J. C. Branner
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DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 38

PERIDOTITE OF ELLIOTT COUNTY, KENTUCKY

WASHINGTON
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1887

ADVERTISEMENT.

[Bulletin No. 38.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880-'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881-'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882-'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883-'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

The Sixth and Seventh Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, IX, X, and XI are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price $1.15.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 243 pp. 56 l. 56 pl. Price $2.70.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl. Price $1.75.

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The following is in press, viz:

XII. Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons. 1886. 4°. xxix, 770 pp. 45 pl. and atlas of 35 sheets folio.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

— Gasteropoda of the New Jersey Cretaceous and Eocene Marls, by R. P. Whitfield.

— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

— Lake Bonneville, by G. K. Gilbert.

— Sauropoda, by Prof. O. C. Marsh.

— Stegosauria, by Prof. O. C. Marsh.

— Brontotheridæ, by Prof. O. C. Marsh.

— Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker.

— The Penokee-Gogebic Iron-Bearing Series of North Wisconsin and Michigan, by Roland D. Irving.

— Younger Mesozoic Flora of Virginia, by William M. Fontaine.

— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.

— Report on the Denver Coal Basin, by S. F. Emmons.

— Report on Ten-Mile Mining District, Colorado, by S. F. Emmons.

— Report on Silver Cliff Mining District, by S. F. Emmons.

— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins contains but one paper and is complete in itself. They are, however, numbered in a continuous series, and may be united into volumes of convenient size. To facilitate this, each Bulletin has two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 38 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining values of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hille- *1885. 8°. 114 pp. 1 pl.* Price 10 cents.

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21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md., by George H. Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second contribution to the studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. A systematic review of our present knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a preliminary study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by Joseph S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. The Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of fine Solid particles in Liquids, by Carl Barus. 1887. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V. Volume VI is not yet complete.

The following are in press, viz:

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham.

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis.

41. Fossil Faunas of the Upper Devonian—the Genesee Section, by Henry S. Williams.

42. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist.

43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In preparation:

44. Historic statement respecting geologic work in Texas, by R. T. Hill.

45. The Nature and Origin of Deposits of Phosphates of Lime, by R. A. F. Penrose, jr.

46. Bibliography of North American Crustacea, by A. W. Vogdes.

— The Gabbros and associated rocks in Delaware, by F. D Chester.

— Report on Louisiana and Texas, by Lawrence C. Johnson.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE or MONEY ORDER (not stamps), should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., April 15, 1887.

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No. 38

WASHINGTON
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1887

[redacted]

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

PERIDOTITE

OF

ELLIOTT COUNTY, KENTUCKY

BY

J. S. DILLER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

CONTENTS.

ILLUSTRATIONS.

PERIDOTITE OF ELLIOTT COUNTY, KENTUCKY.

By J. S. Diller.

INTRODUCTION.

Several years ago Prof. A. R. Crandall, of the Geological Survey of Kentucky, discovered dikes of an interesting eruptive rock between Isom's and Critche's Creeks, near Fielden post office, 6 miles southwest of Willard, in Elliott County, Kentucky. The position of these dikes is shown upon two of the geological maps of Eastern Kentucky. Both maps were prepared under the supervision of John R. Procter, the director of the Kentucky Geological Survey, by Professor Crandall and J. B. Hoeing. One, on a scale of about 4 miles to an inch, is designed to show the relation of the conglomerate uplifts and the dikes; the other, on a scale of 2 miles to an inch, gives the areal distribution of the dikes, the Coal Measures, and the conglomerate in Elliott County. In a vertical section on the same sheet the relations of these terranes are illustrated.

A chemical analysis of the dike rock was made by Messrs. A. M. Peter and J. H. Kastle, in the laboratory of the Geological Survey of Kentucky. Samples of the same material were sent to the United States Geological Survey for microscopic examination. It was found to be a peridotite, and a brief notice of its occurrence was published in Science, January 23, 1885, page 65.

At the request of Mr. Procter and with the approval of Capt. C. E. Dutton and the Director of the United States Geological Survey, I joined Professor Crandall in an excursion to the dikes to collect a complete series of specimens for petrographic investigation.

DISTRIBUTION AND MODE OF OCCURRENCE.

The accompanying map, Plate I, was prepared by enlarging a small portion of the map of Elliott County and introducing the additional data obtained during our late excursion.

At my request, Professor Crandall, who has visited the region a number of times, kindly furnished the following field notes:

This dike represents an eruption of very limited extent laterally, being found only in a small part of the valley of the Little Fork of the Little Sandy River. From its limited range, and also from the readiness with which the rock of which it is composed disintegrates, it does not appear as a noticeable factor in the topography of the

region, and it is with some difficulty that it can be traced beyond the exposures which mark a few points along its surface prolongation. It appears to extend in two diverging lines from Critche's Creek into the valley of Isom's Creek, with several minor offshoots of undetermined but doubtless limited extent, possibly no more than wedge-like projections from the main dike between the strata of the Coal Measures which make up the whole height of the hills of this region. The whole length of the dike in its greatest surface extension appears to be less than a mile, with a width of from a few feet to fifty or more, as indicated by one exposure near Isom's mill, though the slight local disturbance of the including rocks and the inconsiderable metamorphic action, as well as the limited area, indicate no great mass of the intrusive rock. These considerations and some of the conditions noted at Isom's mill suggest the possibility that the exposure there shows a local lateral expansion, rather than the width of the dike. All the rocks of this part of the coal field, including the beds up to coal seven (the Coalton coal of Kentucky, the Sheridan and Nelsonville of Ohio), are cut by both arms of the dike.

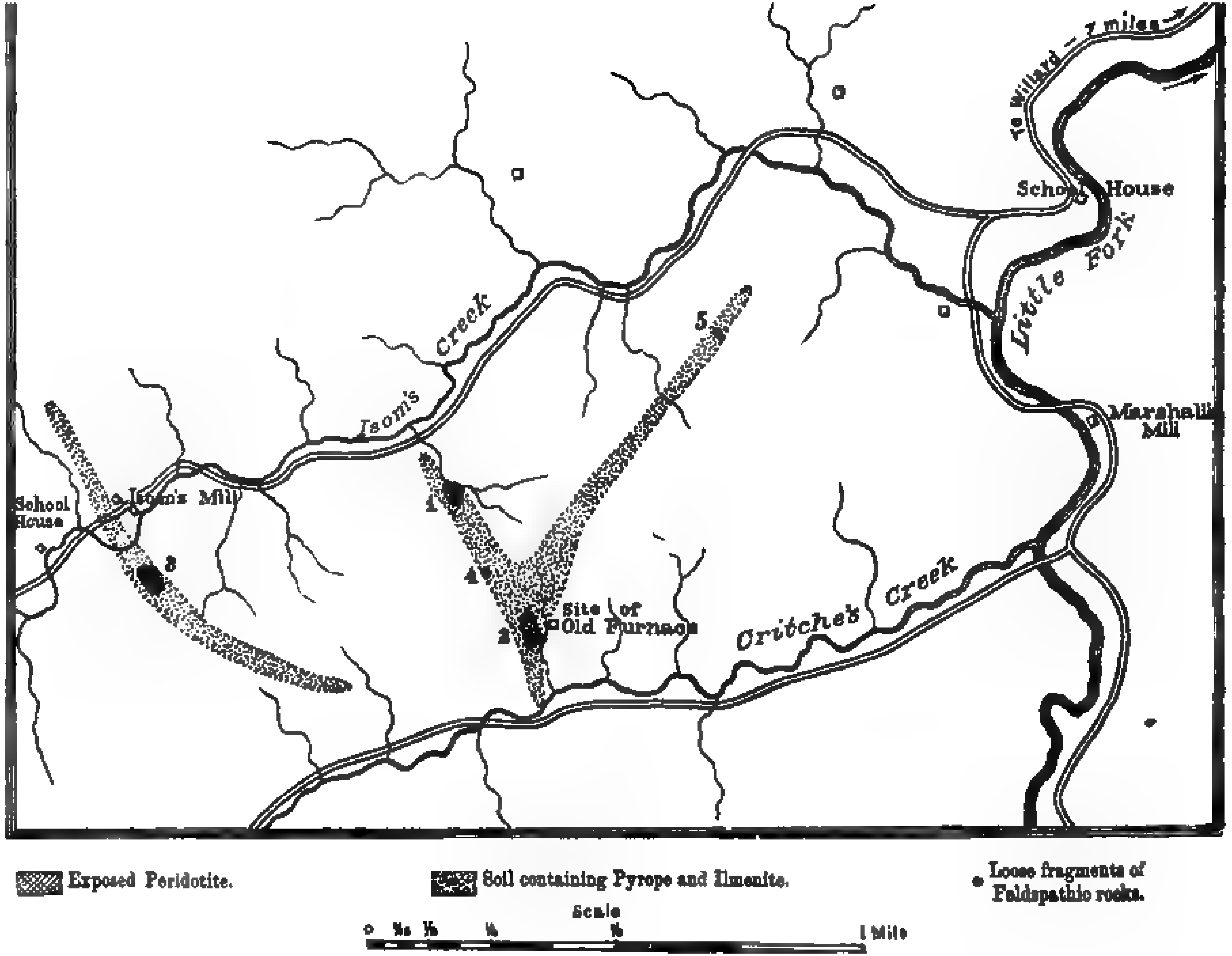
Although there are but three localities where the peridotite is exposed, its areal distribution, as indicated upon the accompanying map (Plate I), can be made out with a high degree of probability by the occurrence of numerous small fragments of ilmenite and pyrope in the soil resulting from its decomposition.

MINERALOGICAL COMPOSITION AND STRUCTURE.

The best and freshest specimens of peridotite were collected at locality marked 1 upon the map, where the specimens were prepared for the educational series. It is a compact, dark greenish rock, with a specific gravity of 2.781. In it are embedded many grains of yellowish olivine, uniformly distributed throughout the mass. Rarely it is fine granular and dense, like many darker colored basalts, but generally the grains of which it is composed are medium sized. Occasionally the olivine grains disappear and the deep green serpentine pervades the whole mass. Besides the olivine and serpentine, which together form nearly 75 per cent. of the rock, there are other minerals which appear in the hand specimen. Most important among these are pyrope and ilmenite, the latter appearing in the form of irregular grains which sometimes attain a diameter of nearly 2 centimeters. A few scales of biotite may be observed. Near the exposed surface the rock becomes yellowish, due to the oxidation of the iron, and softens so that it readily disintegrates. The garnet and much of the ilmenite withstand the atmospheric influences and are found quite fresh and abundant in the sand resulting from the disintegration of the peridotite.

The specimens from localities 1 and 2, the exposures of the eastern dike, are free from included fragments of the rocks through which the peridotite has been extravasated; but those from locality 3, in the western dike near Isom's mill, are full of fragments of shale, which have been greatly indurated and metamorphosed in the operation.

The following table is based directly upon estimates made under the microscope of the areal distribution of the various minerals in the



To Willard — 7 miles
School House
Little Fork
Marshall Mill
Isom's Creek
Isom's Mill
School House
Site of Old Furnace
Critche's Creek
1
2
3
4
5
Exposed Peridotite.
Soil containing Pyrope and Ilmenite.
Loose fragments of Feldspathic rocks.
Scale
1 Mile

freshest portions of the sections from locality 1, where the peridotite is less altered than at any of the other exposures:

Primary minerals.		Secondary minerals.	
	Per cent.		*Per cent.*
Olivine	40	Serpentine	32.7
Enstatite	1	Dolomite	14
Biotite	1	Magnetite	2
Pyrope	6	Octahedrite	1.1
Ilmenite	2.2		
Apatite	Trace		

It is not claimed, of course, that this table represents with a high degree of accuracy the mineralogical composition of the rock, yet it closely approximates the real proportions in the sections studied. The table clearly indicates that originally at least 80 per cent. of the rock was olivine and that ultimately it will be nearly all serpentine—or, perhaps, in some places dolomite—with a small proportion of magnetite, ilmenite, garnet, and octahedrite.

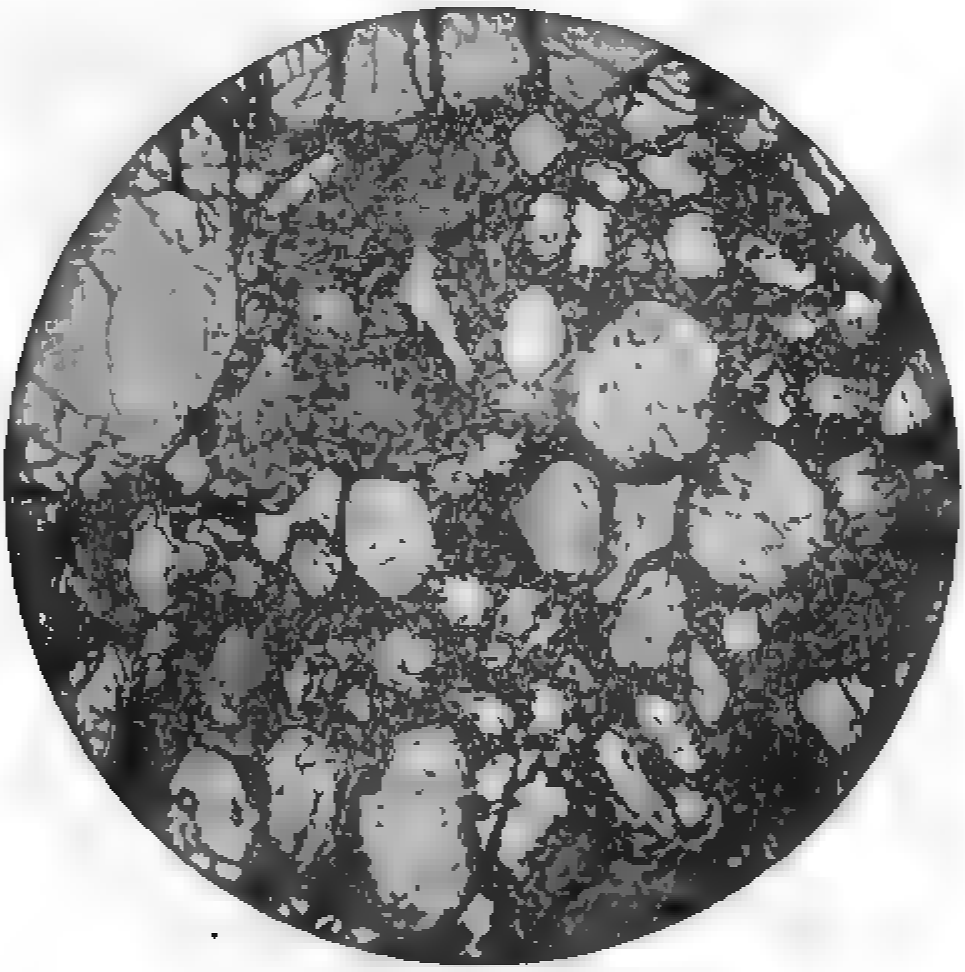


FIG. 1. Section of peridotite seen under the microscope.

The general structure of the rock is illustrated in Fig. 1, which shows the remaining grains of olivine inclosed in a network of serpentine with other products of alteration. The high proportion of olivine in the rock places it among those peridotites which are generally designated dunites, but the presence of some enstatite shows its relationship to another member of the same family.

forming to the embayed contour. This border is irregular in structure and composition, but is almost always present. Where most prominent it is formed of acicular crystals radiating from the enstatite, but generally it is composed of translucent grains of pyroxene rendered somewhat clouded, apparently by the secretion of ferritic matter. The fibrous mineral is transparent, with strong double refraction and small angle of extinction, indicating that it is hornblende.

The embayments of the irregular enstatite sometimes contain olivine, demonstrating that the pyroxene is an earlier product of crystallization than the olivine and owes its border, at least in part, to the subsequent corrosive action of the magma.

The mica is dark colored, strongly dichroic, with a very small optic axial angle in the plane of the principal ray of the radial figure (Schlagfigur) produced by puncturing a thin plate of the mica with a sharp needle. It doubtless belongs to the biotite series and is sparingly distributed throughout the rock. Figure 5 represents a cross section of a somewhat uncommon scale of brown biotite made up of laminæ differing from one another in pleochroism. The foliæ forming the top and the base of the scale, the shaded portions in Fig. 5, are more deeply colored and strongly dichroic than the light brown portion in the middle. All portions are optically continuous and surrounded by a prominent border composed of colorless mica and oxide of iron. The mica of the border is continuous with the other, and evidently owes its loss of color to leaching out the oxide of iron. With the exception of fine ferritic dust irregularly scattered throughout the scales of mica it is generally free from inclusions. One scale, however, has prominent deep brown isotropic inclusions which lie in the basal plane. They look very like basaltic hornblende in ordinary transmitted light, but the entire absence of double refraction and consequent properties clearly demonstrates that if the substance is crystalline in structure it must belong to the isometric system. It is perhaps significant that the axes of greatest extension in the inclusions are approximately parallel to three sets of sharp fissures which apparently correspond to the rays of the peculiar figure developed by pressure, the so-called Druckfigur. The general appearance of the biotite conveys the impression that it has undergone conditions detrimental to its existence and must belong to the earliest products of crystallization. Of this we have convincing evidence in its relations to other minerals, for biotite is frequently included in olivine. Rarely the biotite is surrounded by an irregular secondary border composed of magnetite and biotite differing widely in pleochroism from the biotite within the border. The biotite of the grain and its border are optically continuous, but, while the pleochroism of the

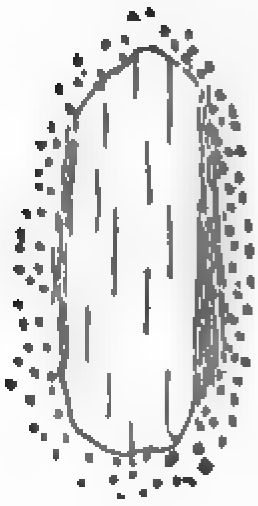


FIG. 5. Biotite.

former ranges from almost colorless to light brownish yellow, that of the latter in corresponding positions is orange-yellow and green.

The relation of the biotite to the garnet is of especial interest and will be noted in discussing the composition of that peculiar envelope in which the pyrope is inclosed. It is evident, however, that the biotite upon the periphery and in the fissures of the garnet is of secondary origin.

Pyrope cannot be considered one of the essential minerals in this rock, yet it is among the most prominent. It occurs in spherical and ellipsoidal grains varying from 1 millimeter to more than a dozen millimeters in diameter. They are found abundantly along the line of the dike in the soil resulting from its disintegration. The small, clear, deep red grains have a specific gravity of 3.673 and are locally regarded as rubies of problematical value, but the paler red, much fractured fragments of larger size have attracted little attention.

The most interesting feature of the pyrope is prominent under the microscope, where it is seen to be surrounded by a border of radial fibers analogous to that described by Fr. Becke[1] and A. Schrauf,[2] and later critically examined by A. v. Lasaulx.[3] The general character of the border is represented in Fig. 6. It is composed of two essentially different substances, both of which are always present, although varying much in proportions. First of these may be mentioned a dark powder, which is frequently so abundant as to render the border opaque. It occurs most abundantly in the outer portion of the border and is chiefly, if not wholly, magnetite; for when carefully detached by a sharp needle from an uncovered section it is found to be strongly magnetic. The second usually inner substance of the ring is of a grayish or reddish brown color and is generally fibrous in structure. Schrauf studied the fibrous substance enveloping the garnets in the serpentine of Kremze, Bohemia, and named it kelyphite. The investigations of Lasaulx have shown that in some cases the border instead of being a single mineral is a mixture of several minerals, chiefly of the pyroxene and amphibole groups. In the example under consideration its composition appears to be exceptional. Although it is commonly made up of closely compacted,

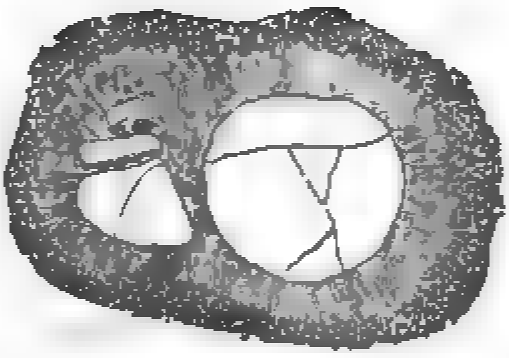


FIG. 6. Pyrope, showing border of biotite and magnetite.

[1] Tschermak's Mittheilungen, iv, 1881, pp. 189, 285.

[2] Beiträge zur Kenntniss des Associations-kreises der Magnesia-Silikate. Zeitschrift für Krystallographie, 1882, VI., pp. 321–388; also Ueber Kelyphite. Neues Jahrbuch, 1884, Bd. II, p. 21.

[3] Ueber Umrindungen von Granat. Sitzungsberichte der niederrhein. Gesellschaft, Bonn, 1882, Juli 3; Verhandlungen des naturhistorischen Vereins der preussischen Rheinlande und Westfalens. Neununddreissigster Jahrgang, zweite Hälfte, Bonn, 1882, p. 114.

very fine, parallel fibers perpendicular to the outer surface of the garnet, it frequently appears as an irregular, non-fibrous fringe upon the inner side of the border, or even completely inclosed within the garnet, where it is usually of a deep brown color. Generally it is distinctly doubly refracting, and when finely fibrous is sometimes strongly colored red and green between crossed nicols. The non-fibrous form of the substance, although deeply colored, is isotropic and consequently not dichroic, but when fibrous the absorption parallel to the fibers is occasionally almost complete. On account of the fineness of the fibers and the density of their aggregation it is not possible to determine the angle of extinction with great precision; nevertheless if the extinction is not parallel the angle is very small indeed. Although many of these borders have been studied about the pyrope in the peridotite from Kentucky, I have not been able to discover convincing evidence of the presence of either pyroxene or hornblende; on the contrary, the evidence clearly indicates that the mineral belongs to the mica group. This conclusion is completely demonstrated by a border, part of which is represented in Fig. 7.

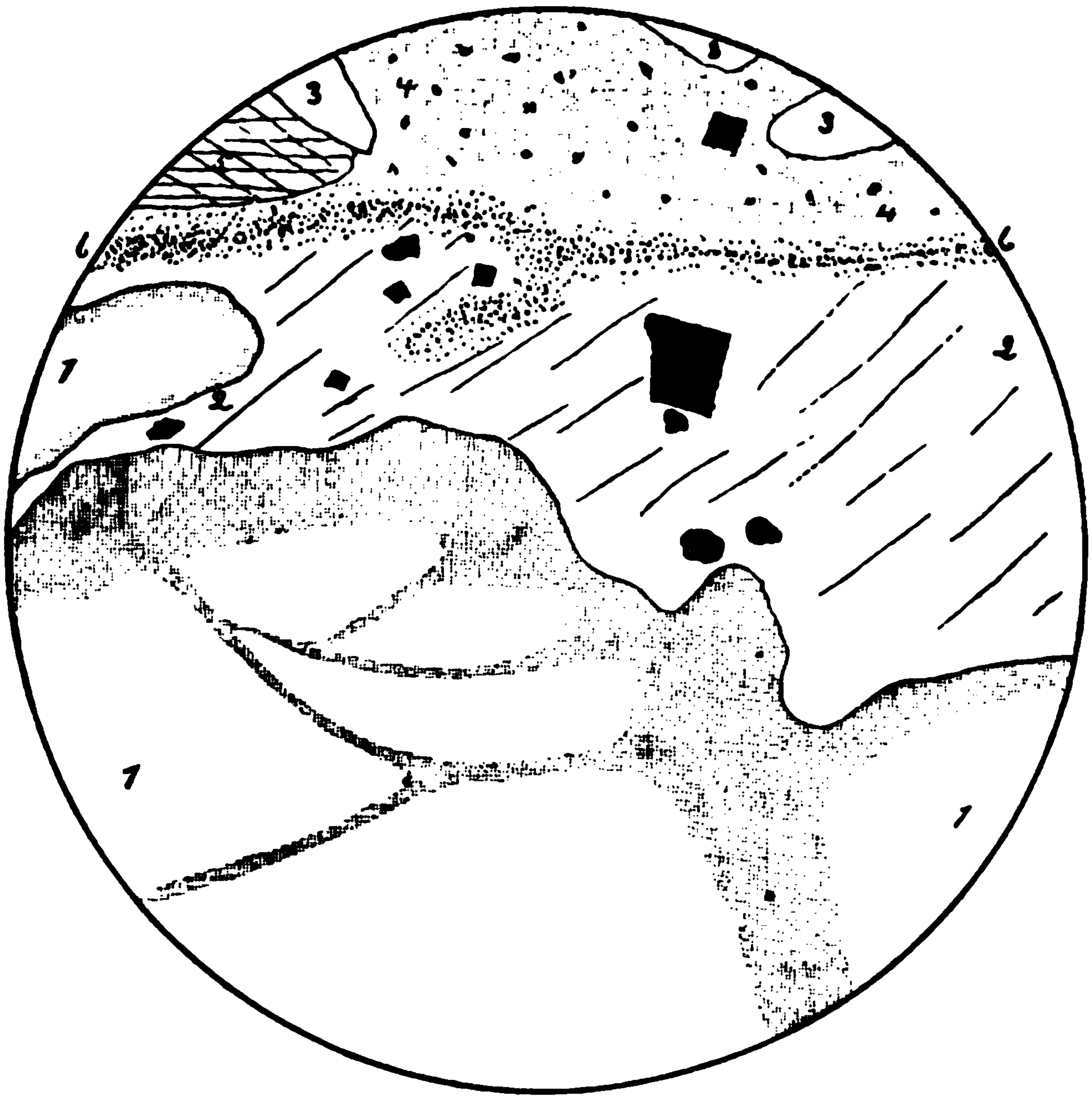


FIG. 7. Part of a border about a grain of pyrope, magnified 80 diameters.

In this case, although the border is not so prominently marked about the whole circumference of the garnet (5 millimeters in diameter) as that represented in Fig. 6, yet there are narrow places along the border where it is distinctly fibrous and grades directly into that represented in Fig. 7 in such a way as to show that both are of the same substance. The uniaxial, negative, strongly dichroic foliated mineral numbered 2

in Fig. 7 is undoubtedly biotite. It extends far into the garnet along fissures and contains besides magnetite small triangular and quadratic sections as well as irregular grains of a yellowish brown isotropic mineral, which in all probability is picotite. The first sight suggests that this deep brown mineral is hornblende, but the absence of all pleochroic phenomena and its regular octahedral form clearly indicate that it cannot belong to the amphibole group. One small pseudomorph after garnet deserves special mention, in that the whole of the middle portion is composed of picotite, which is surrounded by a broad border of magnetite. In the majority of cases, especially where the border is fibrous, the fibers are in direct contact with the clear garnet, but in the section of which Fig. 7 represents a part, where the biotite and picotite are much better developed, the garnet near the border and along fissures is clouded. Besides the biotite and picotite within the compass of the garnet's border, there are traces of calcite and a clear colorless mineral, which, on account of its strong double refraction and the absence of cleavage, is regarded as quartz. It is interesting to note that the quartz almost always occurs in immediate contact with the picotite.

That the shell frequently found about the garnets in peridotitic rocks is composed in most cases essentially of minerals belonging to the pyroxene and amphibole groups has been demonstrated by a number of observers, but as far as I am aware the occurrence of biotite in this connection is here noted for the first time.

It is evident, from the facts represented in Figs. 6 and 7, as already suggested by Lasaulx and Rosenbusch,[1] that the pyrogenic origin of the shell of iron-magnesian silicates frequently enveloping the garnet is generally untenable. The manner in which the enveloping substance is sometimes included in the garnet and penetrates the garnet along fissures clearly demonstrates its secondary origin.

The pyrope, from Kentucky, was carefully analyzed by T. M. Chatard, with the results given in the table of analyses, page 24. It was impracticable to obtain sufficient of the border for chemical examination. The position of the pyrope in the series denoting the order of crystallization is between enstatite, a serpentinous pseudomorph of which it includes, and olivine. Its relation to the primary biotite is not easily determined, from the fact that where the two minerals are found together the biotite is always a secondary product.

Ilmenite is a common and uniformly distributed constituent of the Kentucky peridotite. It is plainly visible in the freshly fractured rock, where it appears in the form of brilliant black grains, varying in size from 1 millimeter to 15 millimeters in diameter. Although subject to considerable alteration it frequently withstands meteoric influ-

[1] H. Rosenbusch: Mikroskopische Physiographie der petrographisch wichtigen Mineralien. Zweite gänzlich umgearbeitete Auflage, 1885, p. 269.

ences with remarkable persistence, appearing abundantly with the garnet in the soil resulting from the disintegration of the peridotite. It is only by means of the ilmenite and pyrope in the soil, as indicated upon the map, that the limits of the dikes can be approximately determined. The ilmenite is readily distinguished from the magnetite, even under the microscope in reflected light, by the brilliant luster of portions of its pitted surface. It has always been observed in large grains and not in the form of fine, spongy particles like magnetite. Under the microscope the ilmenite is frequently seen surrounded, penetrated, and even completely replaced by a mixed group of yellowish and black grains resulting from its alteration. The black opaque grains are magnetite and the yellowish ones probably octahedrite. The specific gravity of the ilmenite is 4.453 and a chemical analysis of it is given in the table, page 24.

Near the southern end of the eastern dike, at a point indicated upon the map, is a prehistoric embankment which appears to have been the foundation for works to smelt the peridotite, probably on account of the supposed value of the bright ilmenite it contains.

Magnetite is abundantly distributed throughout the whole rock. It rarely occurs in the form of well developed octahedrons, but appears generally in irregular, spongy grains a small fraction of a millimeter in diameter. The magnetite results chiefly from the alteration of the olivine and ilmenite, and is therefore rarely, if ever, observed as veritable inclusions in the primary minerals.

The particles picked out of the rock powder by the magnet were treated to an acidulated solution of sulphate of copper in water, and after their removal examination under the microscope showed that many of the grains were coated with copper, indicating that some of the iron was present in the peridotite in a native state.

Abundantly scattered among the other secondary products in the serpentinous network enveloping the remnants of olivine are yellowish clouded grains ranging in size from .004 to .06 millimeters in diameter. The intensity of the yellowish color varies considerably, with a strong inclination towards brown. Its index of refraction is very high, causing it to rise above the neighboring minerals, but its low grade of translucency scarcely more than allows the observer to discover that the mineral is distinctly doubly refracting without determining certainly its degree. The relation of this mineral to the ilmenite clearly indicates that it results from the alteration of the latter and at once suggests that it is a mineral with much titanium, probably titanite or one of the forms of titanic oxide. This is clearly demonstrated by its chemical reactions. With a very sharp steel point a number of these grains were removed from an uncovered section. In the same way a small particle of ilmenite about half replaced by yellow grains adhering to it was isolated. In both cases the material was dissolved in fused $KHSO_4$, and when the product was moistened with a solution of H_2O_2 it turned distinctly yel- *indicating the* presence of titanium. The grains are compact and

generally spherical, or at most not more than twice as long as thick. Not infrequently one discovers bounding planes to these grains in the sections that are straight and sharply defined, indicating crystallographic form. Such cases are generally accompanied by a higher degree of transparency and are triangular, square, or diamond shaped. When diamondshaped the grains are most strongly doubly refracting and extinction takes place parallel to the longest diagonal. No trace of cleavage could be discovered, nor could the system of crystallization be determined with certainty, but the facts mentioned render it highly probable that the mineral is octahedrite. The occurrence of octahedrite as an alteration product of ilmenite was observed by the author several years ago in "Schalstein" from Hof in the Fichtelgebirge, Germany.[1] Cohen and Rosenbusch,[2] had previously called attention to the same phenomenon in other localities.

Under the microscope the rock is seen to contain an abundance of carbonate irregularly distributed among the secondary minerals. It is plainly a product of alteration, chiefly of the olivine. It is not affected by warm acetic acid, but effervesces vigorously in ordinary hydrochloric acid. After the calcium has been removed from the solution sodium phosphate yields an abundant crystalline precipitate, showing the presence of magnesia and demonstrating that the carbonate is dolomite. It rarely accumulates in nodules as large as a hazel nut and only at points where the rock is highly altered. The high percentage of lime and carbonic acid present in the peridotite, as shown by chemical analysis No. 4, in the table, page 24, indicates that there is about 14 per cent. of dolomite present and that the carbonate of lime largely predominates in its composition. In some cases, as noted by Dr. M. E. Wadsworth[3] and Prof. R. D. Irving,[4] peridotite is almost completely replaced by dolomite resulting from its alteration.

Next to olivine, serpentine is the most important mineral of the rock, and it occurs in two forms: first in the form of small green scales, which, with dolomite, magnetite, ilmenite, and octahedrite, compose the network in which the remaining olivine is inclosed; frequently, however, the olivine has entirely disappeared, and its place in the meshes is represented by yellowish serpentine, quite unlike the first in its color and inclusions. The first form is bright green of varying intensity, but rarely pleochroic, and it has weak double refraction, yielding between crossed nicols a peculiar bluish aggregate polarization. Its appearance under the microscope is like that of chlorite, but, when isolated and treated with sulphuric acid and cæsium chloride, it did not show the presence of alumina.

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[1] Anatas als Umwandlungsproduct von Titanit in Biotitamphibolgranit der Troas. Neues Jahrbuch, Vol. I, 1883, p. 187.

[2] H. Rosenbusch: Mikroskopische Physiographie der petrographisch wichtigen Mineralien. Band II, p. 336; also, Zweite Auflage, Band I, p. 332.

[3] Lithological studies: Memoirs of the Museum of Comparative Zoölogy, Cambridge, Mass., Vol. XI, Part I, p. 139.

[4] *Fifth Annual Report United States* Geological Survey, 1883-'84, p. 217.

Strongly contrasted with the green foliated serpentine is the yellowish fibrous form which with dolomite fills the meshes. It is often distinctly fibrous, and sometimes between the fibers are small radial aggregates which show a distinct cross between opposed nicols. The fibers are sometimes distinctly dichroic; the ray oscillating parallel to the longest axis is yellow and perpendicular to it pale greenish, but generally it is not perceptibly dichroic. This form of serpentine, although free from the larger inclusions so common in the other, contains great numbers of small black grains not more than .002 of a millimeter in diameter. These black grains are probably the magnetite secreted in a very fine form in the process of serpentinization, for this serpentine is slightly magnetic.

RELATIONS AND ORIGIN OF THE PERIDOTITE.

The relation of the peridotite to the carboniferous sandstones and shales is of paramount importance in determining its age and origin. Although it has been repeatedly spoken of as a dike the evidence has not yet been fully presented to establish its eruptive character. Concerning the relation of the peridotite to its associated rocks only two hypotheses are worthy of consideration: (1) the peridotite may be older than the carboniferous strata and may have formed on the floor of the sea a peak about which the horizontal strata were deposited; (2) the peridotite may have been erupted through the carboniferous strata. If the first hypothesis is correct we would expect to find the adjacent sandstone composed largely of detritus derived from the peridotite and to exhibit no evidence of contact metamorphism. On the other hand, if the second hypothesis is true, there would not necessarily be a correspondence in the composition of the neighboring rocks, and under favorable conditions the sedimentary deposits would be metamorphosed near their contact with the eruptive.

The rocks of the neighborhood are so disintegrated and covered with soil that notwithstanding our careful search we were unable to discover an exposure of the junction between the two rocks. Nevertheless sufficient evidence has been collected to definitely settle the problem under consideration. Very near an outcrop of the peridotite at locality 1 occurs a calcareous sandstone of which mineralogical and chemical analyses have been made. It is composed of quartz with a smaller proportion of triclinic feldspar, bent scales of muscovite, and biotite, all of which are cemented by carbonate of lime. The quartz grains are distinctly subangular and not infrequently contain minute needles of rutile. The sandstone is conspicuously unlike the adjacent peridotite in its composition and clearly indicates that the peridotite was not in its present position at the time the sandstone was deposited. This difference is further emphasized by the chemical analysis, No. 7, page 24. When it is compared with the analysis of the peridotite (No. 4) from the same locality the dissimilarity is so prominent as to dispel at once the thought that they may be genetically connected.

This discordance in the composition of the two rocks stimulated the

hope of discovering evidence of contact metamorphism, and in this we were not disappointed, for at locality 3 hardened shale was found near the peridotite under such circumstances that its induration is certainly attributable to the influence of the eruptive mass. The effects produced by the peridotite upon the adjacent sedimentary rocks may be considered first and subsequently those experienced by the peridotite itself near the contact. For convenience the shale may be regarded as made up of two classes of constituents, (1) the grains of sand and (2) the matrix or cement in which they are embedded. Among about a dozen specimens of the shale examined the relative proportions of the sand grains and cement vary greatly. In one case the former predominates, so that the rock may be regarded as a fine-grained sandstone, but generally the earthy cement is in excess and frequently forms almost the whole mass. Some of the clear grains are quartz, but most of them are of orthoclase, microcline, or plagioclase feldspar. The matrix varies greatly, consisting chiefly where least altered of a heterogeneous clayey substance containing a multitude of microlites,[1] numerous small scales of mica, and particles of black organic pigment with a trace of magnetite.

The metamorphic influence of the peridotite is clearly traceable in the distribution of the pigment and the development of a crystalline structure in the cement. The latter becomes more and more micaceous in character as the metamorphism increases, and the parallel arrangement of the foliæ renders the rock more easily split, sometimes even fissile in one direction. The distribution of the pigment is generally uniform throughout the mass, but in a portion of one of the sections it is clearly aggregated into groups, giving the section a mottled appearance, and approaches in character the so-called Knotenthonschiefer so admirably investigated by Rosenbusch.[2] The name spilosite has been used to designate such rocks in the contact zone about basic eruptive masses. The dark spots (Knoten) are not visible in the hand specimens, but may be plainly seen in the section and appear to be completely isotropic. The lighter colored areas among these show between crossed nicols doubly refracting grains, which are chiefly mica associated with feldspar. Chemical analysis No. 9 was made of a fragment of indurated shale in which the microscopic spots were most distinctly observed. Analysis No. 10 is of a fragment of shale included in the peridotite. The size and abundance of the mica scales in the altered shale is in a general way proportional to the intensity of the metamorphic influence. A person is frequently surprised, however, to find small fragments of shale, less than a centimeter in diameter, completely enveloped by the peridotite and yet not extremely metamorphosed. In many cases the small fragments are almost completely altered to micaceous minerals,

[1] These microlites correspond exactly to those so frequently observed in clay-slate and in a number of cases have been demonstrated to be rutile. H. Rosenbusch: Mikroskopische Physiographie der petrographisch wichtigen Mineralien. Zweite Auflage, p. 304.

[2] Die Steiger Schiefer und ihre Contactzone an dem Granititen von Barr-Andlau und Hohwald.

which appear to be of several sorts. A portion is completely colorless and when examined in converging light between crossed nicols is found to be distinctly biaxial, but the hyperbolæ when farthest apart do not quite reach the outer limit of the field of vision. It is strongly doubly refracting, with the peculiar sheen commonly observed in muscovite. The other mica is more or less distinctly colored, being greenish or yellowish bordering upon brown, and is distinctly dichroic light to dark yellowish green. It occurs in irregular scales and fibers, with strong double refraction, and appears to be nearly or altogether uniaxial. The colorless mica is frequently continuous with that which contains considerable coloring matter, and I have frequently been in doubt as to the presence of more than one kind of mica.

The included fragments of shale are always surrounded by a border of colorless mica whose scales are intricately intermingled. Frequently, although not generally, the foliæ have their greatest dimension at right angles to the surface of the inclusion. This border varies in width, but is usually about 3 millimeters in thickness and composed almost exclusively of well developed irregular scales of colorless mica. The same mineral is distributed quite abundantly in the enveloped fragment. It appears also sparingly scattered for a short distance away upon the outside of the border among the serpentine and other alteration products of the peridotite. The brownish colored mica, which is so common in the altered shale adjacent to the peridotite, appears very different in the included fragments, where a higher degree of alteration has taken place. It here appears to be a gray, clouded, translucent mass, which, between crossed nicols, is seen to be made up of scales of mica. This advanced stage of metamorphism in the included fragments is accompanied by the appearance of very interesting bodies which have not been definitely determined. They are pale yellowish in color, translucent to almost transparent, and perfectly isotropic. The diameter of these little balls is generally about .02 of a millimeter and they are remarkably uniform in size and shape. In general appearance they closely resemble the small translucent grains of octahedrite in the adjacent peridotite, but they cannot be octahedrite, for they are soluble in hydrochloric acid. When a flake of mica containing them is heated to a bright red heat they become less translucent and somewhat more earthy in appearance, but the change is not prominent. In the small fragments the globules are usually numerous, scattered throughout the scales of clouded mica, but most abundant and less regular in form near the border of the inclusion, where they sometimes produce a quite distinct band just inside the one of colorless mica. In the fragments where this peculiar isotropic substance is most abundant there is but little well developed mica. Traces of other unimportant minerals occur under such circumstances as to render their determination a matter of great difficulty. Rarely among the scales of clear mica in the border which always surrounds included fragments of shale, may be observed ngated particles of a deep brown mineral, which in ordinary trans-

mitted light resembles hornblende, but is not pleochroic, has weak double refraction and an extinction angle of about 37 degrees. The recent discovery that the Kimberley and other diamond mines of South Africa are upon volcanic necks of peridotite penetrating carbonaceous shale[1] attaches much interest to the peridotite of Kentucky, where similar geologic relations exist. Diamonds have not yet been discovered in Kentucky. The shale in the immediate vicinity of the dikes does not appear to be sufficiently rich in carbonaceous matter to excite much enthusiasm.[2]

An endomorphic effect experienced by the peridotite near its contact with the sedimentary rocks is apparently discernible in a structure which may be regarded as variolitic in character. The peridotite at this point contains many fragments of included shale, but in the hand specimens one sees nothing resembling a variolite. In a few of the thin sections, however, here and there among the olivine and its alteration products may be observed light brown, translucent, homogeneous, compact bodies similar in general appearance to the isolated sphærolites which sometimes occur in fresh andesitic rocks. Lighter colored veinlets run through them and between crossed nicols they are seen to be radially fibrous and show a distinct but not sharply defined black cross. The quadrants are rather intensely but not brilliantly red, yellow, or green, with a peculiar fuzzy appearance. These varioles are seen only in sections containing inclusions of shale and appear to be most abundant in their neighborhood; but, on the other hand, small included fragments of shale are frequently observed without any such structure near them.

The facts which indicate the relation of the peridotite to the adjacent carboniferous strata may be briefly recapitulated. In mineralogical and chemical composition the two rocks are very unlike. The carboniferous shales near their junction with the peridotite are greatly indurated by the development of a crystalline structure, which as it augments obliterates the sedimentary character and gives rise to a schistose arrangement of the particles. Fragments of shale of various sizes are included in the peridotite and have been greatly metamorphosed. On the other hand, the peridotite near its junction with the sedimentary rocks, owing to their influence upon it, has locally developed a variolitic structure such as has been not infrequently observed in diabases and other eruptive rocks near their contact with older formations. These facts demonstrate beyond a doubt that the peridotite is a truly eruptive rock which has been forced up through the carboniferous strata. Peridotites are common rocks, but they are almost always associated with others of a highly crystalline character in regions of great disturbance, and their origin cannot be clearly demonstrated. By many authors they are regarded as eruptive, but by others they are considered to belong to sedimentary formations. In one of the very

[1] H. Carvill Lewis: The Genesis of the Diamond, Science, Vol. VIII, p. 345.

[2] *The Genesis of the Diamond*, Science, Vol. VIII, p. 392, October 29, 1886.

latest works on lithology[1] they are included among "katogene" rocks, i. e., rocks which, like sandstone, are formed of material deposited at a level lower than its source. In this country the dunite associated with the corundum deposits of North Carolina has been regarded by Dr. A. A. Julien,[2] who studied the rocks both in the field and under the microscope, as a deposit of olivine sand derived from an earlier eruptive mass. Dr. M. E. Wadsworth,[3] after a critical examination, considered them to be eruptive, and my investigations of the same rocks convince me that Dr. Wadsworth's conclusion is correct. The dunite of North Carolina and the one in Elliott County, Kentucky, are essentially the same in structure and composition, and I believe are also of the same eruptive origin. Certain it is that the one in Kentucky is eruptive, and all the essential phenomena in North Carolina point in the same direction. It is important to note, however, a marked difference in the character of the alteration in the two cases. In the dunite of North Carolina, as well as in a number of undescribed peridotites of Northern California and elsewhere,[4] which like it are found associated with highly contorted and metamorphosed strata, the olivine frequently alters to hornblende. In Kentucky, however, where regional metamorphism is entirely absent, no such alteration has been observed.

CHEMICAL COMPOSITION.

The following table presents in a concise form all of the chemical analyses which have been made of the peridotite, its constituents, and associated rocks:

Chemical analyses of peridotite and associated rocks.

	(1) Olivine.	(2) Pyrope.	(3) Ilmenite.	(4) Peridotite.	(5) Peridotite.	(6) Granite.	(7) Calcareous sand stone near peridotite.	(8) Fine grained fissile sandstone near dike.	(9) Indurated shale near dike.	(10) Fragment of shale included in peridotite.
Water at 110° (H_2O)	0.14	0.17	0.20	8.92	10.90	0.51	0.65	1.94	......	1.40
Water at red heat (H_2O)	0.66	......	......	......	......	......	2.32	5.17	8.78	9.00
Carbonic acid (CO_2)	......	......	......	6.66	5.05	......	6.20	......	0.55	0.68
Silicic acid (SiO_2)	40.05	41.32	0.76	29.81	29.43	60.56	60.78	60.25	41.32	35.53
Titanic acid (TiO_2)	0.07	0.16	49.32	2.30	1.48	1.19	0.03	0.22	0.48	0.96
Phosphoric acid (P_2O_5)	0.04	None	Trace	0.35	Trace	0.30	0.09	0.10	0.08	0.48
Chromic oxide (Cr_2O_3)	0.24	0.91	0.74	0.43	0.14	......	......	......	Trace	......
Alumina (Al_2O_3)	0.39	21.21	2.84	2.01	2.36	16.19	10.54	20.18	20.71	18.22
Ferric oxide (Fe_2O_3)	2.36	4.21	0.13	5.16	......	5.19	3.27	1.63	2.59	2.46
Ferrous oxide (FeO)	7.14	7.93	27.81	4.35	9.06	2.41	......	3.43	5.46	4.61

[1] E. Kalkowsky: Elemente der Lithologie, p. 236.

[2] Proceedings Boston Society Natural History, Vol. XXII, p. 141.

[3] Science, Vol. III, p. 286, April 18, 1884.

[4] *Mikroskopische Physiographie der petrographisch wichtigen Mineralien.* Zweite *gänzlich umgearbeitete* Auflage, pp. 412, 413.

Chemical analyses of peridotite and associated rocks—Continued.

	(1) Olivine.	(2) Pyrope.	(3) Ilmenite.	(4) Peridotite.	(5) Peridotite.	(6) Granite.	(7) Calcareous sand-stone near peridotite.	(8) Fine grained fissile sandstone near dike.	(9) Indurated shale near dike.	(10) Fragment of shale included in peridotite.
Manganous oxide (MnO)	0.20	0.34	0.30	0.23	....	0.36	0.10	0.10	0.17	30.1
Nickelous oxide (NiO)	{ (CoO) Trace }	...	....	0.05	0.60	......	......	......	....	......
Lime (CaO)	1.10	4.94	0.23	7.69	6.94	2.09	10.15	0.51	9.91	21.17
Magnesia (MgO)	46.68	10.32	8.68	32.41	31.60	1.30	1.50	3.62	1.91	2.01
Potash (K_2O)	0.21	.....	....	0.20	0.65	4.82	2.30	3.17	0.88	1.08
Soda (Na_2O)	0.08	0.07	0.19	0.11	0.78	4.76	1.41	0.39	7.19	2.58
Sulphur (S)	.....	......	......	None	*0.20	......	......	......	......	......
Sulphuric acid (SO_3)	.....	......	......	0.28	0.30	.....	......	.....	... ..	.....
Total	99.42	100.58	100.10	100.86	100.15	99.70	99.78	100.51	100.03	100.26
Specific gravity	3.377	3.673	4.453	2.781	2.697	2.633	......	.....	....	2.489

*In sulphides.

Analysis No. 5 of the peridotite was made by A. M. Peter and J. H. Kastle in the chemical laboratory of the Geological Survey of Kentucky. All the other analyses were made by T. M. Chatard in the chemical laboratory of the United States Geological Survey.

Although the freshest samples of the peridotite were selected for analysis, the large percentage of water and carbonic acid present indicates a high degree of alteration. As compared with the analyses of other typical peridotites the amount of silica appears very low, but this does not necessarily indicate that any of the silica has been removed, for its apparent decrease is due, at least in large part, to the addition of water and carbonic acid from external sources.

LOOSE FRAGMENTS OF FELDSPATHIC ROCKS FOUND WITH THE PERIDOTITE.

At the localities marked 4 and 5 upon the map loose fragments of highly feldspathic rocks occur upon the surface, mixed with the soil containing garnets and ilmenite. The fragments found at the two places, although somewhat dissimilar, are holocrystalline and granitic in structure, altogether unlike the adjacent sandstones and shales, and it is evident that they belong to the eruptive mass. They deserve special attention and will be noticed separately, beginning with those found upon the hillside at locality 4, a short distance northwest of the site of the old furnace. Several fragments were found at this place, scattered along the border of the dike for a distance of 50 yards. The hand specimen looks very like a rotten syenite and is easily crumbled be-

tween the fingers. Notwithstanding the fact of its feeble cohesion the feldspar, which is by far the most prominent mineral of the rock, exhibits numerous bright cleavage and crystal faces. Dark colored minerals are not conspicuous. Among these, ilmenite may be easily recognized by its jet black color and brilliant luster. Under the microscope the rock is seen to be composed chiefly of feldspar. Considerable quartz and ilmenite are present, with a trace of hornblende, sphene, and apatite. The feldspar is of two sorts, orthoclase and plagioclase, readily distinguished by their optical characters. They are generally grown together as perthite and may be completely irregular in their interlockings, but frequently the parallel sheets of each, varying from .005 to .01 millimeter in thickness, join in the plane of the orthopinacoid and are quite regular in outline. The orthoclase is somewhat clouded by kaolinization, but the plagioclase is colorless and transparent, with bright polarization between crossed nicols. The polysynthetic twinning which characterizes the plagioclase is generally parallel to the clinopinacoid, but frequently associated with these lamellæ are others parallel to the orthopinacoid. Cleavage lamellæ of the plagioclase parallel to the base have a very small angle (2 degrees) of extinction. This fact indicates that the plagioclase is not pure albite, but has a considerable admixture of the anorthite molecule and is probably oligoclase. This conclusion is substantiated by a test with hydrofluorsilicic acid, which shows the presence of both calcium and sodium. The feldspar, especially the perthitic form, contains numerous inclusions. Besides apatite and ilmenite, the earlier products of crystallization, the feldspar contains numerous acicular groups of light brown scales, whose character could not be definitely determined. The scales are frequently hexagonal in form, and although all are in a row their hexagonal planes may make any angle with the longer axis of the group. These acicular groups generally lie at an angle of about 45 or 90 degrees to the plane of the perthitic lamellæ.

Quartz occurs in clear, colorless grains, the uniaxial positive character of which can be easily demonstrated. It contains occasional liquid and gas inclusions, but none of the kind so common in the feldspar. Quartz and feldspar are each included in the other and must have crystallized synchronously. The green dichroic mineral regarded as hornblende does not appear with well defined crystallographic features. It has rather strong double refraction, but the angle of extinction could not be sharply determined in the absence of well defined cleavage. Chemical analysis No. 6 in the table is of this feldspathic rock. Its mineralogical and chemical constitution indicates that it belongs rather to the granites than to the syenites, although it is closely related to the latter group.

The other specimen of feldspathic rock collected near the eastern end of the dike at locality 5 is quite unlike the one just described. The only fragment found in this case is very solid and fresh in appearance and

somewhat gneissoid in structure. In the hand specimen it appears to be composed chiefly of feldspar and garnet and a smaller proportion of a greenish mineral, but in addition to these the microscope reveals the presence of small quantities of quartz, enstatite, apatite, and other accessory minerals. In structure it is holocrystalline and distinctly granular. None of its constituents, excepting the minute acicular inclusions, has a well defined crystallographic outline. The feldspar is plagioclase with a much larger angle of extinction and broader twinning lamellæ than the oligoclase of the other fragment. Orthoclase, if present at all, is rare and does not appear in perthitic growth with plagioclase. Occasionally the feldspar is bent or broken, as if subjected to great strain since its crystallization. Nearly or quite a third of the rock is formed of garnet, which to the unaided eye looks very like the pyrope of the peridotite. It differs from the latter, however, very prominently under the microscope in containing numerous included microlites. These minute acicular crystals are of a yellowish mineral like rutile, but between crossed nicols are seen to be brilliantly doubly refracting with inclined extinction. The angle of extinction varies from 0 degree to 30 degrees, indicating that the mineral crystallizes in the monoclinic system. Cross sections of the small crystals have a rhombic or elliptical outline. Rarely these inclusions are arranged irregularly, but generally they appear to be nearly equally distributed in three sets. The longer axes of the crystals in each set are parallel, but the longer axes of the different sets make an angle of about 45 degrees with one another. Frequently these minute crystals are associated with cavities, as represented in the annexed figure 8.

The first example looks as though the crystal had been formed by partly filling a cavity, of which *a* represents the portion remaining unoccupied. In the second example, however, the cavity *e* is between *b* and *c*, which are optically parallel, indicating that they are parts of the same crystal and that the cavity has been formed by dissolving away its middle portion. Although these inclusions are numerous in the garnet they are even more abundant in the green mineral, which has not been definitely determined. It has almost as high an index of refraction as garnet and is strongly doubly refracting. It is plainly biaxial, with extinction inclined to the indistinct cleavage. The quartz, enstatite, apatite, and a yellowish brown mineral like rutile present nothing worthy of special mention. The structure and mineralogical composition of this rock fragment closely ally it to the granulites.

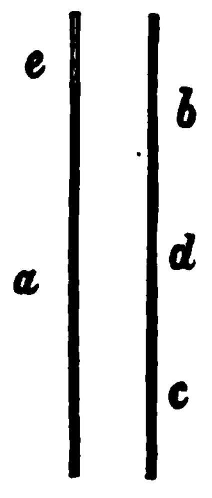

FIG. 8. Included microlites and cavities in garnet.

The presence of the two kinds of fragments of feldspathic rocks intermingled with the soil resulting from the disintegration of the peridotite may be explained in many ways, but from the fact that the dike occurs in nearly horizontal, unaltered, stratified rocks, many scores of miles

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DEPARTMENT OF THE INTERIOR

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OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 39

THE UPPER BEACHES AND DELTAS OF THE
GLACIAL LAKE AGASSIZ

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

ADVERTISEMENT.

[Bulletin No. 39.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

The Sixth and Seventh Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, IX, X, and XI are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price $1.15.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 243 pp. 56 l. 56 pl. Price $2.70.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl. Price $1.75.

The following is in press, viz:

XII. Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons. 1886. 4°. xxix, 770 pp. 45 pl. and atlas of 35 sheets folio.

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The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

— Gasteropoda of the New Jersey Cretaceous and Eocene Marls, by R. P. Whitfield.

— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

- Lake Bonneville, by G. K. Gilbert.

— Sauropoda, by Prof. O. C. Marsh.

— Stegosauria, by Prof. O. C. Marsh.

— Brontotheridæ, by Prof. O. C. Marsh.

— Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker.

— The Penokee-Gogebic Iron-Bearing Series of North Wisconsin and Michigan, by Roland D. Irving.

— Younger Mesozoic Flora of Virginia, by William M. Fontaine.

— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.

— Report on the Denver Coal Basin, by S. F. Emmons.

— Report on Ten-Mile Mining District, Colorado, by S. F. Emmons.

— Report on Silver Cliff Mining District, by S. F. Emmons.

— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins contains but one paper and is complete in itself. They are, however, numbered in a continuous series, and may be united into volumes of convenient size. To facilitate this, each Bulletin has two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 39 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.
2. Gold and Silver Conversion Tables, giving the coining values of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.
3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.
4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.
5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.
6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.
7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.
8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.
9. Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.
10. On the Cambrian Faunas of North America. Preliminary studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.
11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.
12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.
13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.
14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.
15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.
16. On the higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.
17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.
18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.
19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.
20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.
21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.
22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

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23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md., by George H. Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second contribution to the studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. A systematic review of our present knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a preliminary study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by Joseph S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. The Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of fine Solid particles in Liquids, by Carl Barus. 1887. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V. Volume VI is not yet complete.

The following are in press, viz:

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis.

41. Fossil Faunas of the Upper Devonian—the Genesee Section, by Henry S. Williams.

42. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist.

43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In preparation:

— Historic statement respecting geologic work in Texas, by R. T. Hill.

— The Nature and Origin of Deposits of Phosphates of Lime, by R. A. F. Penrose, jr.

— Bibliography of North American Crustacea, by A. W. Vogdes.

— The Gabbros and associated rocks in Delaware, by F. D. Chester.

— Report on Louisiana and Texas, by Lawrence C. Johnson.

— On the subaërial decay of rocks and the origin of the red color of certain formations, by Israel C. Russell.

— Bibliography of North American Geology for 1886, by Nelson H. Darton.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE OR MONEY ORDER (not stamps), should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *April 30, 1887.*

DEPARTMENT OF THE INTERIOR

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No. 39

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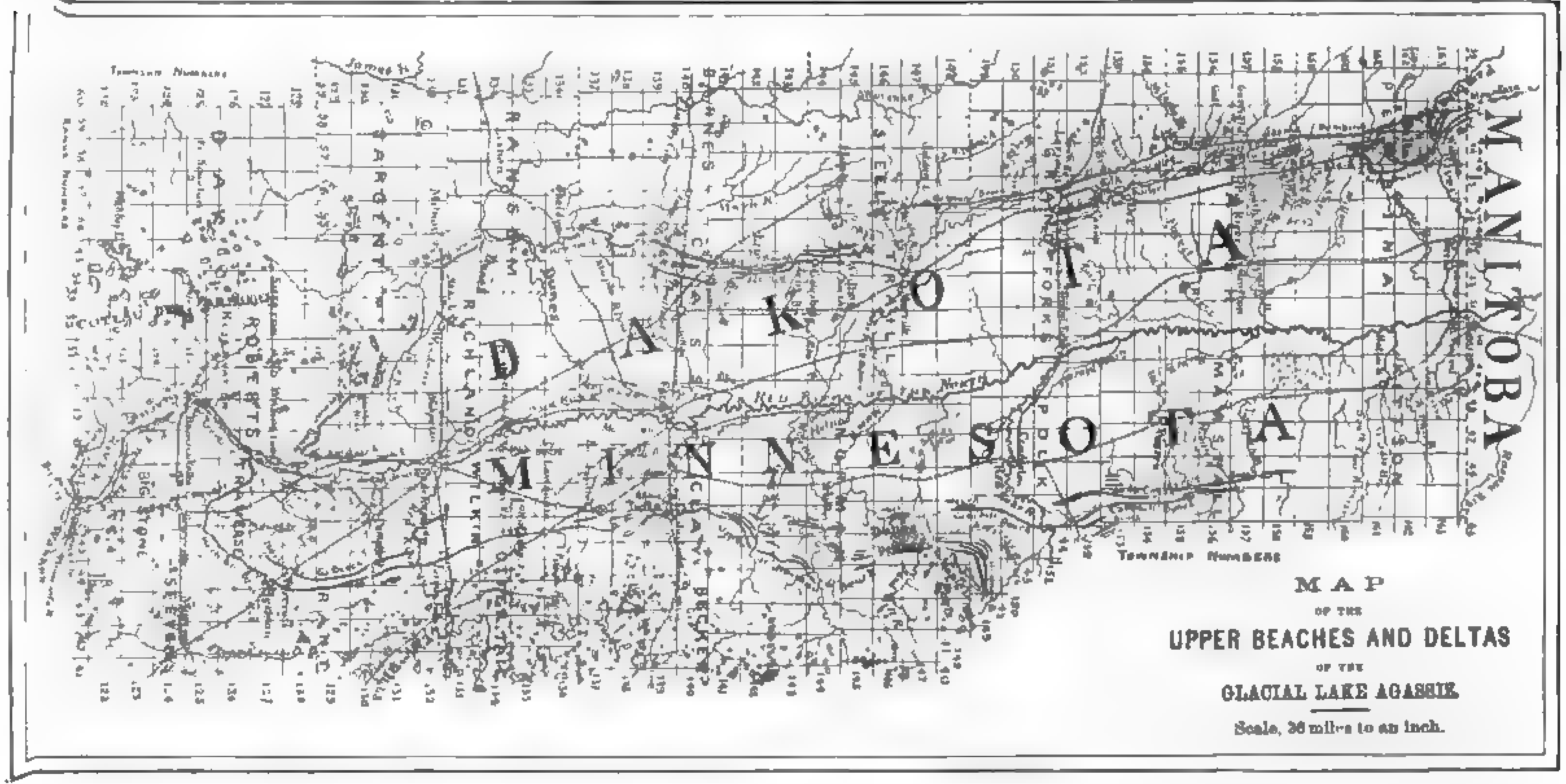
1887


MANITOBA
DAKOTA
MINNESOTA
Township Numbers
Range Numbers
MAP
OF THE
UPPER BEACHES AND DELTAS
OF THE
GLACIAL LAKE AGASSIZ
Scale, 36 miles to an inch.

[redacted]

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

THE UPPER BEACHES AND DELTAS OF THE GLACIAL LAKE AGASSIZ

BY

WARREN UPHAM

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., June 8, 1886.

SIR: I have the honor to transmit herewith for publication as a Bulletin of the Survey a paper embodying the results of the investigations of Mr. Warren Upham, assistant geologist, upon the upper beaches and deltas of the extinct Lake Agassiz, which, in glacial times, occupied the basin of the Red River of the North.

This is but an initial contribution, embracing only so much of the data gathered as from their degree of completeness and interest warrant present publication as a record of results. The investigation is still in progress, and the general discussion of data and the eduction of conclusions are reserved until its completion. Meanwhile the great mass of carefully determined facts here recorded will, besides their inherent independent value, be of important and immediate service to the students of other extinct and shrunken glacial lakes.

Very respectfully,

T. C. CHAMBERLIN,
Geologist in Charge of Glacial Division.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

UPPER BEACHES AND DELTAS OF LAKE AGASSIZ.

By WARREN UPHAM.

INTRODUCTION.

That part of the extinct Lake Agassiz which lies in Minnesota, so far as it is prairie, was explored by the writer in 1879 and 1881 in connection with the Geological and Natural History Survey of Minnesota, the results of which are partly used in the preparation of this report for the purpose of giving completeness and significance to the observations obtained in the survey to which this bulletin more especially relates.[1]

Further exploration of this lake was begun for the United States Geological Survey by the writer, with Robert H. Young as assistant, in 1885, mapping the upper or Herman beaches in Dakota from Lake Traverse to the international boundary, besides portions of the lower shore lines, with exact determinations of their elevation by leveling. As the Herman beaches and deltas are thus surveyed along the entire extent of Lake Agassiz in the United States, excepting the wooded region of Northern Minnesota, where their exact survey seems impracticable, they are made the subject of the present report, reserving the detailed description of the lower beaches and the inclosed lacustrine area until their exploration within the United States is finished, for which the field work of 1886 will probably suffice.

Discussions of the history of Lake Agassiz and of the causes that have changed the relations of surfaces of level here are mainly deferred to the end of the examination of the whole area of this lake. Observations gathered thus completely may be reasonably expected not only to add much to our knowledge of the conditions attending the glacial

[1] The Geological and Natural History Survey of Minnesota, Eighth Annual Report (1879), pp. 84 to 87, containing a general statement of the extent of this lake, with notes of its beaches and deltas at a few points, and proposing for it the name Lake Agassiz; and Eleventh Annual Report, pp. 137 to 153, describing and mapping the Herman, Norcross, and Campbell beaches, noting the decrease in the northward ascent of the lake level during its successive stages, and attributing these changed levels to the attraction of the lake by gravitation toward the diminishing ice sheet. This work in Minnesota was done under the direction of Prof. N. H. Winchell, State geologist, with the assistance in 1881 of Horace V. Winchell as rodman in leveling.

period and the recession of the ice sheet but also to shed needed light on the nature and relations of the earth's crust and interior.

The glacial Lake Agassiz is confidently believed to have been formed in the basin of the Red River of the North and of Lake Winnipeg during the final melting and gradual recession of the ice sheet. It thus belongs to the closing epoch of the ice age, when the continental glacier, subdued by a more temperate climate, was yielding its ground between Lake Traverse and Hudson Bay. During this retreat free drainage from the melting ice could not take place, because the descent of the land is northward. As soon as the border of the ice had receded beyond the watershed dividing the basins of the Minnesota and the Red Rivers, it is evident that a lake, fed by the glacial melting, stood at the foot of the ice fields and extended northward as they withdrew along the Red River Valley to Lake Winnipeg, filling this valley and its branches to the height of the lowest point over which an outlet could be found. Until the ice barrier was melted upon the area now crossed by the Nelson River, thereby draining this glacial lake, its outlet was along the present course of the Minnesota River. At first its overflow was upon the nearly level, gently undulating surface of the drift, about 1,100 feet above the sea; but in process of time this cut a channel 125 to 150 feet deep and from 1 to 2 miles wide, in which lie Traverse and Big Stone Lakes, respectively 970 and 962 feet above the sea. From this outlet the plain of the Red River Valley, 30 to 50 miles wide, stretches 315 miles north to Lake Winnipeg, which is 710 feet above the sea. Along this entire distance there is a very uniform continuous descent of a little less than one foot per mile. The drift deposited by the ice sheet upon this area, together with that which may have been dropped by floating ice borne on the waters of the lake, and the silt brought in by glacial rivers and by those of the surrounding land, were here received in a lake, shallow near its mouth, but becoming gradually deeper northward. Beyond our national boundary this lake covered a large area, varying from 100 to 200 miles in breadth at and west of Lake Winnipeg, and its total length appears to have been at least 600 miles. Because of its relation to the retreating continental ice sheet, this lake has been named in memory of Prof. Louis Agassiz, the first prominent advocate of the theory that the drift was produced by land ice.[1]

THE UPPER OR HERMAN BEACH.

Along nearly the whole of the upper shore line of Lake Agassiz, as traced in Minnesota and Dakota, there exists a remarkable deposit of beach gravel and sand, forming a continuous, smoothly rounded ridge, such as is found along any part of the shores of the ocean or of our great

[1] The Geological and Natural History Survey of Minnesota, Eighth Annual Report, for the year 1879, pp. 84, 85.

lakes where the land sinks in a gently descending slope beneath the water level. Usually the beach of Lake Agassiz (Fig. 1) is a ridge 3 to 10 feet above the land next to it on the side away from the lake and 10 to 20 feet above the land adjoining it on the side where the lake lay. In breadth this beach ridge varies from 10 to 25 or 30 rods. It is thus a broad wavelike swell, with a smooth, gracefully rounded surface.

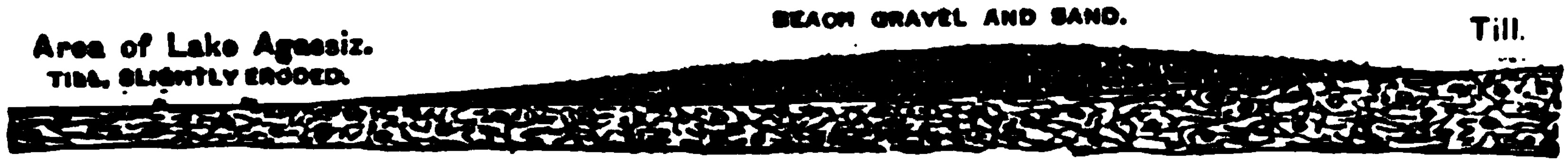

FIG. 1. Typical section across a beach ridge of Lake Agassiz.

Such being a section across the beach, it is to be remembered that this ridge extends along the whole distance that has been explored, with only here and there gaps where it has been cut through by streams and rare intervals—of a quarter or a half of a mile, or, at the longest, 2 or 3 miles—where the outline of the lake shore or the direction of the shore currents prevented such accumulation. It is also deficient on the shores of the strait that occupied the Elk and Golden Valleys in Dakota, but is well developed along the chain of islands east of this strait. There are similar interruptions in the beaches of present lakes and on the sea coast; and, like these modern deposits, the beach of Lake Agassiz varies considerably in its size, having in any distance of 5 miles some portions 5 or 10 feet higher than others, due to the unequal power of waves and currents at these parts of the shore. The usually moderate slope of the land toward Lake Agassiz was favorable for the formation of a beach ridge, and one has been clearly traced as an essentially continuous formation along a distance of 400 miles in Minnesota and Dakota. In calling it continuous, I mean to say that whenever interrupted it is found a little distance farther along, beginning again at very nearly the same height.

The gaps where the beach is not a distinctly traceable ridgelike deposit of gravel and sand cannot exceed one-tenth of its whole course. In a few places the lake undermined its shore, forming a terrace in the till, with no definite beach deposit, the work of the waves having been to erode and carry away rather than to accumulate. In other places—sometimes 2 or 3 miles in length—the area where this ancient lake had its margin is a marsh or shaking bog, full of spring water and rough with hummocks of grass.

Commonly the land upon each side of this beach of Lake Agassiz is till or unstratified clay, containing some intermixture of sand and gravel and occasional stones and bowlders. The material of the beach ridge is remarkably in contrast with this adjoining and underlying till, for it includes no clay, but consists of stratified sand and gravel, the largest pebbles being usually from 2 or 3 to 6 inches in diameter. No bowlders referable to transportation by floating ice have been found in any of the beach deposits of this lake.

When Lake Agassiz stood at its greatest height and formed the upper beach, its outlet was about 75 feet above the present surface of Lake Traverse, or 1,045 feet above the sea. The channel which at this time had been excavated in the drift by its outflow was 40 to 50 feet deep along the distance of about 50 miles, where are now Lake Traverse, Brown's Valley, and Big Stone Lake. This beach is crossed by the Breckenridge line of the Saint Paul, Minneapolis and Manitoba Railway at a point about 1½ miles northwest from Herman, Minnesota.

THE NORCROSS BEACH.

Three lower beaches, of the same character as to form, size, and material with the highest, have been also noted; their course has been traced through long distances and their height has been determined by leveling. At the next epoch after that of the upper or Herman beach, when the lake level was again nearly stationary long enough to form a ridge of gravel and sand upon its shore, the outlet had been eroded about 20 feet deeper than at the time of the upper beach, but was still 55 feet above the present Lake Traverse and Brown's Valley. The beach of Lake Agassiz, when it had this lower level, is crossed by the Breckenridge railway line at Norcross, Minnesota, 5 miles northwest from Herman.

THE CAMPBELL BEACH.

A third series of beach deposits was formed when the outlet of Lake Agassiz had been lowered some 50 feet more, nearly to the level of Lake Traverse. The beach of this third stage of Lake Agassiz takes its name from the township of Campbell (T. 130, R. 46), in the southern part of Wilkin County, Minnesota, which it crosses from southwest to northeast.

THE M'CAULEYVILLE BEACH.

The fourth and lowest beach of Lake Agassiz, while it outflowed to the south, was formed after a further erosion of 15 feet, lowering the outlet to 960 feet above the sea and completing the excavation of its channel to the present beds of Traverse and Big Stone Lakes. My first observation of this beach was 3½ miles northeast from McCauleyville (T. 134, R. 48), in Wilkin County, Minnesota.

Four distinct series of beach ridges of gravel and sand were thus formed by Lake Agassiz at successive stages of height during its process of deepening the channel by which it outflowed southward.

THE RED RIVER VALLEY.

The central part of the basin of Lake Agassiz, within the limits of Minnesota and Dakota, now drained by the Red River, has an exceedingly flat surface, sloping imperceptibly northward, as also from each side to its central line. The Red River has its course along the axial depression, where it has cut a channel 20 to 60 feet deep. It is bordered by only few and narrow areas of bottom land, instead of which

its banks usually rise steeply on one side and by moderate slopes on the other to the lacustrine plain, which thence reaches nearly level 10 to 30 miles from the river. Its tributaries cross the plain in similar channels, which, as well as the Red River, have occasional gullies connected with them, dry during most of the year, varying from a few hundred feet to a mile or more in length. Between the drainage lines areas often 5 to 15 miles wide remain unmarked by any watercourses. The highest portions of these tracts are commonly from 2 to 5 feet above the lowest.

This vast plain, 40 to 50 miles wide, lying half in Minnesota and half in Dakota and stretching from Lake Traverse and Breckenridge north to Winnipeg, is the widely famed Red River Valley, the most fertile wheat land of the continent. The material of the lower part of this ancient lake bed, shown in the banks of the Red River and reaching several miles from it, is fine clayey silt, horizontally stratified, but its south end and large areas of each side of this plain are mainly unstratified bowlder clay, which differs from the rolling or undulating till of the adjoining region only in having its surface nearly flat. Both these formations are almost impervious to water, which therefore in the rainy season fills their shallow depressions; but these are very rarely so deep as to form permanent lakes. Even sloughs that continue marshy through the summer are infrequent, but where they do occur they cover large tracts, usually several miles in extent.

On all the area drained by the Red River in Minnesota the glacial drift is so thick that no exposures of the underlying rocks have been found, and they have only few outcrops within this basin in Dakota. The depth of the drift varies from 100 to 250 feet. The prominent topographic features of all this region are doubtless due to the form of the underlying rock surface, upon which the drift is spread in a sheet of somewhat uniform thickness.

Erosion, before the ice age, had sculptured the rocks that are buried and concealed under this universal drift sheet and had formed the broad, nearly level depression of the Red River Valley, which in the United States is 1,000 to 800 feet, from south to north, above the sea. Slopes and terraces of these rocks beneath the drift cause the rise eastward from this valley to the lake-sprinkled plateau, 1,300 to 1,500 feet above the sea, which reaches from Glenwood, Alexandria, and Fergus Falls to the sources of the Mississippi. For example, though the traveler finds no ledge of rock in going from the Red River at Fargo and Moorhead 75 miles east-northeast to Itasca Lake, it yet appears that the form of the surface, marked by two remarkable terraces, is due to that of the bed rock. The flat of the Red River Valley extends from Moorhead to about 6 miles east of Glyndon, with a slight ascent of about 50 feet in these 15 miles. The next 2 or 3 miles rise 200 feet to the top of a terrace, which reaches from south to north the whole length of

the Red River Valley in Minnesota, though it is not all the way so distinct nor so high as here. Beyond this ascent the surface is again nearly level, being a sheet of slightly undulating or rolling till, with a rise of perhaps 4 or 5 feet per mile, through 25 miles eastward. Next is a terrace, also reaching a long distance from south to north, which is ascended in 3 or 4 miles, rising about 300 feet, to the White Earth Agency, which thus commands a very extensive western prospect. Thence a more rolling plateau extends, with little change in the average height, 30 miles eastward to Itasca Lake.

In like manner the elevation of the Coteau des Prairies, 1,500 to 2,000 feet above the sea, and the terracelike ascent at the west side of the flat Red River Valley in Dakota, lying at a distance of 20 to 35 miles west of the Red River and stretching from the south bend of the Sheyenne River north to the British line, where it is called Pembina Mountain, are due to the contour of the bed rock, rather than to differences in the thickness of the drift.

The till upon each side of Lake Agassiz has a moderately undulating and rolling surface. Within the area that was covered by this lake it has a much smoother and more even contour, but has been only slightly stratified. The action of its waves gathered from this deposit of till, which was the lake bed, the gravel and sand of its beaches; and corresponding deposits of stratified clay, derived from the same erosion of the till, sank in the deeper part of the lake. But these sediments were evidently of small amount and are not noticeable upon the greater part of this lacustrine area, which consists of a smoothed sheet of till. The position of the thick beds of stratified fine silt and clay in the central depression of the Red River Valley shows that they were not deposited by the waters of Lake Agassiz, which must have spread them more generally over its entire area; but, instead, proves that they were brought by the rivers which flowed into this hollow and along it northward after the glacial Lake Agassiz had been reduced to its present representative, Lake Winnipeg. The occurrence of shells and remains of vegetation in these stratified beds at McCauleyville 32 and 45 feet below the surface, or about 7 and 20 feet below the level of the Red River, and numerous other observations of remains of vegetation elsewhere along the Red River Valley in these beds, demonstrate that the valley was a land surface, subject to overflow by the river at its stages of flood, when these remains were deposited. Even at the present time much of the area of stratified clay is covered by the highest floods, and probably no portion of these stratified deposits is more than 10 feet above the high water line of the Red River and its tributaries.

THE OUTLET OF LAKE AGASSIZ.

The excavation of the remarkable valley occupied by Lakes Traverse and Big Stone and the Minnesota River was first explained in 1868 by General G. K. Warren, who attributed it to the outflow from this ancient

lake that filled the basin of the Red River and Lake Winnipeg. He made a careful survey of this valley from Lake Traverse to its mouth, and his maps and descriptions, with the accompanying discussion of geologic questions, are most valuable contributions to science.[1] After his death, in recognition of this work, the glacial river that was the outlet of Lake Agassiz was named River Warren.[2]

The heights of Lakes Traverse and Big Stone are, respectively, 970 and 962 feet above the sea, and the lowest point of the divide between them is only 3 feet above Lake Traverse. These lakes are from 1 to 1½ miles wide, mainly occupying the entire width of this troughlike valley, which is inclosed by bluffs of till about 125 feet high. Lake Traverse is 15 miles long; it is mostly less than 10 feet deep and its greatest depth probably does not reach 20 feet. Big Stone Lake extends in a somewhat crooked course from northwest to southeast 26 miles; its greatest depth is reported to be from 15 to 30 feet. The portion of the channel between these lakes is widely known as Brown's Valley. As we stand upon the bluffs here, looking down on these long and narrow lakes and the valley which extends across the 5 miles between them, where the basins of Hudson Bay and the Gulf of Mexico are now divided, we have nearly the picture that was presented when the melting ice sheet of British America was pouring its floods along this hollow. Then the entire extent of the valley was doubtless filled every summer by a river which covered all the present areas of flood plain, in many places occupying as great width as these lakes. General Warren observed that Lake Traverse is due to a partial silting up of the channel since the outflow from the Red River basin ceased, the Minnesota River at the south having brought in sufficient alluvium to form a dam, while Big Stone Lake and Lac qui Parle are similarly due to the deposits of stratified sand and silt which the Whetstone and Lac qui Parle Rivers have spread across the valley below them.

THE NORTHERN BARRIER.

The northern barrier by which the water of Lake Agassiz was restrained from flowing in the direction of the present drainage to Hudson Bay was supposed by General Warren to have been an elevation of the land much above its present height northeast of Lake Winnipeg.

[1] "On certain physical features of the Upper Mississippi River," American Naturalist, Vol. II, pp. 497–502, November, 1868. Annual Report of the Chief of Engineers, United States Army, for 1868, pp. 307–314. "An essay concerning important physical features exhibited in the valley of the Minnesota River, and upon their signification," with maps, Report of Chief of Engineers, 1875. "Valley of the Minnesota River and of the Mississippi River to the junction of the Ohio. Its origin considered—depth of the bed-rock," with maps, Report of Chief of Engineers, 1878, and American Journal of Science, (3) XVI, pp. 417–431, December, 1878. (General Warren died August 8, 1882.)

[2] Proceedings of the American Association for the Advancement of Science, Vol. XXXII (for 1883), pp. 213 to 231; also in American Journal of Science, (3) XXVII, January and February, 1884; and Geology of Minnesota, Vol. I, p. 622.

He thought that this elevation was shared by other northern portions of North America and that these regions have recently been depressed at least several hundred feet. The depths of the great lakes and many topographic features of the interior of the continent, besides this channel of Lakes Traverse and Big Stone and the Minnesota River, appeared to him to support this opinion. On the contrary, my belief is that the surface of the continent had nearly the same form then as now and that the continental ice sheet, resting on the land in a solid mass of great depth, formed the northern shore of Lake Agassiz and was the barrier that prevented it from flowing into Hudson Bay.[1]

The four series of beach deposits which mark the shores of Lake Agassiz at as many stages of its height are found to have a gradual ascent northward, as compared with the present level line or the surface which a body of water would have now if confined in this valley. As before stated, these beaches were formed at epochs when the lake level was nearly stationary for a considerable time during the excavation of its channel of outlet at Lake Traverse and southward.

Exploration and leveling along the upper beach in Minnesota extended from the north end of Lake Traverse about 25 miles eastward to Herman, and thence about 140 miles north to Maple Lake. Through this distance it lies from 15 to 30 miles east of the Red River. The ascent of this beach northward is at a rate that increases from 6 inches to 1 foot a mile in its southern portion for about 75 miles. Farther north its rate of ascent increases from 1 foot to 16 inches a mile. In all, the surface of Lake Agassiz in Minnesota at this time of its greatest height ascended northward, above a line now level, 125 feet in these 140 miles, from 1,045 feet, very nearly, above sea at Lake Traverse, to 1,170 feet, very nearly, at the north side of Maple Lake, 20 miles east-southeast from Crookston. Through this distance the upper beach clearly marks one continuous shore line.

Before Lake Agassiz had fallen below the line of this beach in the south half of its explored extent, it had formed a slightly lower parallel beach, three-fourths of a mile to 1½ miles distant, through the northern third of Clay County; and this secondary beach, sometimes double or treble, was noted at several places along the next 30 miles northward. At the northwest side of Maple Lake definite beach ridges were formed when Lake Agassiz had fallen in that latitude successively about 8, 15, 30, and 45 feet from its highest level. Yet all these beaches were accumulated while the lake remained with only very slight depression of

[1] That this lake existed because of the barrier of the receding ice sheet was pointed out by Prof. N. H. Winchell in his First Annual Report of the Geological and Natural History Survey of Minnesota, for 1872, p. 63, and in his Sixth Annual Report, for 1877, p. 31. He also explained in like manner the formerly higher levels of the great lakes, Popular Science Monthly, June, 1873; and the same view is stated by Prof. J. S. Newberry in Report of the Geological Survey of Ohio, Vol. II, 1874, pp. 6, 8, and 51.

level, not sufficient for the formation of any secondary beach ridge, along its southern part for some 75 miles northward from Lake Traverse and Herman.

The Norcross beach in Minnesota has been explored and its height measured through the same distance of 140 miles, in which it ascends northward about 62 feet by a slope that increases slightly from south to north, averaging nearly 6 inches a mile. The surface of Lake Agassiz had fallen at this time from its highest level 20 feet at Lake Traverse, 50 feet in Northern Clay County, and 83 feet northwest of Maple Lake. Its fall in this extent had been thus 63 feet more at the north than at the south. Double and multiple ridges occur along the northern half of this distance and show that the lake level at the time of formation of the Norcross beach fell 5 to 10 feet northward, while it remained without change or with less change than was required to form additional beach ridges southward.

The heights of the Campbell and McCauleyville beaches in Minnesota are known for a distance of 150 miles, in which the northward ascent of the lake level during the Campbell stage was about 37 feet and during the McCauleyville stage 25 feet. The fall of Lake Agassiz from the upper or Herman beach to the McCauleyville beach was 85 feet at its mouth and 185 feet near Maple Lake; and, instead of the northward ascent of the upper beach 125 feet in 140 miles, this had been gradually diminished to 117, 110, 95, 80, 62, 50, 37, and finally 25 feet at the time of the formation of the McCauleyville beach.

In Dakota the same series of beaches are found and they have been traced along the whole or parts of their course, with determination of their elevations, to a distance about 75 miles farther north than in Minnesota. In 224 miles from Lake Traverse to the international boundary the lake level in Dakota at its highest stage, during the time of formation of the first Herman beach, ascended northward about 185 feet, from 1,045 to 1,230 feet above the sea; during the time of the first Norcross beach it ascended 120 feet, from 1,025 to 1,145 feet; during the time of the Campbell beach it ascended 65 feet, from 975 to 1,040; and during the time of the first McCauleyville beach it ascended 35 feet, from 960 to 995 feet above our present sea level. A later McCauleyville beach shows only 25 feet ascent in these 224 miles, or an average of 1¼ inches a mile.

Comparison of the elevations of these beaches in Dakota and Minnesota at the same latitude reveals another very interesting feature of the levels of this glacial lake, namely, an ascent from west to east similar to that from south to north, but of less amount and diminishing in a similar ratio between the successive stages of the lake. On the latitude of Larimore and Grand Forks the ascent of the lake surface above a line now level was approximately 33 feet, at the time of the first Her-

man beach, in about 70 miles from west to east, the rate per mile being very nearly half as much as from south to north; and during the time of formation of the later Herman beaches it diminished to 30, 26, and 21 feet. When the first and second Norcross beaches were formed this ascent toward the east was 14 and 11 feet in about 60 miles, and during the Campbell and McCauleyville stages it was reduced to only 6 and 4 feet in about 50 miles; yet it continues through all these stages approximately half as much per mile as the ascent toward the north. The rate of ascent eastward also increased, like that northward, in proceeding from south to north. At the latitude of Wahpeton and Breckenridge, 35 miles north from the mouth of Lake Agassiz, the ascent of the lake level in its highest stage was 10 feet from west to east in 45 miles; at the latitude of Fargo and Moorhead, 75 miles north from the outlet, it was 15 feet in 50 miles; and at the latitude of Grand Forks, 150 miles north from the outlet, it was 33 feet in 70 miles, approximately. The accompanying table shows the relations of these beaches and the changes which took place in surfaces of level here during the existence of this glacial lake.

If the barrier north and northeast of Lake Agassiz had been land, its subsidence to give way for drainage northward in its present course to Hudson Bay would cause the beach deposits of the former lake shores to have the opposite slope, or a descent from south to north and from west to east. These observations are therefore inconsistent with such explanation of the cause of this lake; but they appear to prove that its northern barrier was the receding continental glacier. I have thought that all the differences of the once level lines of Lake Agassiz from our present level line might have been produced by the gravitation of the water of the lake toward the ice sheet. At first this attraction would have been relatively large, because of the nearness of the great mass of ice on the northeast in Minnesota and northward in British America; but as the ice retreated it must have been gradually diminished and reduced to a comparatively small influence by the time the ice sheet had withdrawn so as to permit the northward drainage of the lake.

Among other agencies that have been proposed to account for such changes are (1) effects due to the weighting of the earth's crust by the ice and its removal; (2) the cooling and contraction of the crust by the ice and glacial waters, and the subsequent warming and expansion owing to the amelioration of the climate; and (3) crust changes of unknown origin, having no relationship to the glacial phenomena.[1] These several agencies will receive studious consideration in my final report, when a more extended range of observations will come under review.

[1] Prof. T. C. Chamberlin, Geology of Wisconsin, Vol. I, 1883, p. 290, and Proc. Am. Assoc. Adv. Sci., Minneapolis meeting, Vol. XXXII, 1883, page 212; also, paper before Philosophical Society, Washington, March 13, 1886.

Mr. G. K. Gilbert, American Journal of Science (3), XXXI, pp. 290–299, April, 1886

AREA AND DEPTH OF LAKE AGASSIZ.

The beaches of Lake Agassiz, as here described in Dakota and from Lake Traverse and Herman north to Maple Lake, in Minnesota, extend through a prairie region very favorable for exploration and leveling. The farther course of the upper beach turns to the east and northeast and lies in a trackless forest, much of which consists of almost impassable tamarack swamps. It is therefore quite impracticable to trace its course exactly through this wilderness; but, from the known elevation of Red Lake (about 1,150 feet above the sea), of the Lake of the Woods (1,062 feet), and of Rainy Lake (about 1,120 feet), the outline of Lake Agassiz when it had its greatest height can be mapped approximately.

From the north side of Maple Lake this outline extends eastward, passing south of Red Lake, across the Big Fork of Rainy River, and along the south side of Rainy Lake, its height above Red and Rainy Lakes being probably about 50 and 150 feet, respectively. Thus Lake Agassiz at this time of greatest height reached along the international boundary farther east than the meridians of Minneapolis and Saint Paul. Its expanse included only few islands, these being of small area and near the shore.

When this glacial lake attained its greatest extent, it probably exceeded Lake Superior, both in length and in area. At the time of the formation of its highest beach the depth of Lake Agassiz above Fargo and Moorhead was nearly 200 feet; above Grand Forks and Crookston, a little more than 300 feet; and above Pembina and Saint Vincent, about 450 feet.

In the following tabulations the figures represent the height, in feet, above sea level, where not otherwise stated.

The letters *a*, *b*, *c*, *d*, represent successive beaches along the northern part of Lake Agassiz, which seem to be merged in a single beach toward its south end.

The columns marked *north ascent* show the ascent of the lake from its south end, which was at Lake Traverse, and those marked *east ascent* show the ascent of the lake from its western to its eastern shore.

The successive elevations of the mouth of Lake Agassiz, situated at its south end (Lake Traverse), were, for the Herman beach, 1,045 feet; for the Norcross beach, 1,025 feet; for the Campbell beach, 975 feet; and for the McCauleyville beach, 960 feet.

Elevations of the crests of the beaches of Lake Agassiz.

[The figures in parenthesis are derived for the boundary line from the nearest observations, chiefly near Walhalla, for which the figures without the parenthesis stand; similarly, the figures in parenthesis for the latitude of Grand Forks are derived from observations near Maple Lake, 15 miles south, for which the figures without parenthesis stand.]

Location.	Herman beach.			Norcross beach.			Campbell beach.			McCauleyville beach.		
		East ascent.	*North ascent.*		*East ascent.*	*North ascent.*		*East ascent.*	*North ascent.*		*East ascent.*	*North ascent.*
(1) On the international boundary line in Dakota, 224 miles north of Lake Traverse. (Only the west or Dakota shore could be examined at the boundary.)	(a) 1,226 (1,235)	....	(185)	(a) 1,140 near Young (1,155).	....	(120)	1,050	....	65	(a) 1,004 (1,006)	....	(35)
	(b) 1,212 (1,220)	....	(166)	(b) 1,141 (1,143)	....	(108)				(b) 992 (994)	....	(25)
	(c) 1,197 (1,202)	....	(149)									
	(d) 1,182 (1,187)	....	(135)									
(2) On the latitude of Grand Forks, 150 miles north of Lake Traverse, west side, in Dakota.	(a) 1,162	....	107	(a) 1,092	....	57	1,014	....	31	(a) 991	....	21
	(b) 1,146	....	93	(b) 1,080	....	47				(b)	....	....
	(c) 1,134	....	80									
	(d) 1,121	....	69									
(2) On the latitude of Grand Forks, 150 miles north of Lake Traverse, east side, in Minnesota.	(a) 1,180 (1,195)	(33)	125 (140)	(a) 1,094 (1,103)	(14)	62 (71)	1,022	6	37	(a) 996	4	25
	(b) 1,165 (1,178)	(30)	110 (123)	(b) 1,082 (1,090)	(11)	50 (58)				(b) 989	....	18
	(c) 1,147 (1,158)	(26)	95 (106)									
	(d) 1,132 (1,141)	(21)	80 (90)									
(3) On the latitude of Fargo and Moorhead, 75 miles north of Lake Traverse, west side, in Dakota.	1,099	....	45	....	....	....	997	....	15	....	....	....
(3) On the latitude of Fargo and Moorhead, 75 miles north of Lake Traverse, east side, in Minnesota.	1,114	15	60	1,065	....	30	1,002	3	18	983	....	13
(4) On the latitude of Wahpeton and Breckenridge, 35 miles north of Lake Traverse, west side, in Dakota.	1,065	....	10	....	....	....	....	....	....	972	....	4
(4) On the latitude of Wahpeton and Breckenridge, 35 miles north of Lake Traverse, east side, in Minnesota.	1,075	10	20	1,045	....	10	992	....	7	....	....	....

THE UPPER OR HERMAN BEACH IN MINNESOTA.[1]

[See the accompanying map, Plate I.]

FROM LAKE TRAVERSE EAST TO HERMAN.

Lake Traverse, elevation 970 feet above the sea.

Bluffs next to Lake Traverse south from the Mustinka River, elevation 1,072 to 1,075 feet above the sea.

Bluffs opposite to these and for 3 or 4 miles northward, on the west side of Lake Traverse, 1,090 to 1,070 feet.

Bluff or ridge forming the highest land between the Mustinka River and the Bois des Sioux River, from Sec. 35 to Sec. 13, T. 128, R. 47 (the west part of Monsen), an island beach ridge of Lake Agassiz during its maximum stage, about 1,050 feet.

Upper or Herman beach in Secs. 2 and 11, T. 126, R. 47 (Walls), 1,060 to 1,062 feet, 4 to 5 miles east from the north end of Lake Traverse, where the steep eroded bluff gives place to the gentle slope of the natural surface, allowing the accumulation of a distinct beach ridge of gravel. This is smoothly rounded, 15 to 20 rods in width, bounded eastward on the side toward the ancient lake by a moderately steep slope which descends 10 or 12 feet, the land 1 to 4 miles distant northeastward within the area that was covered by the lake being 20 to 40 feet below this beach. On the other side this ridge is succeeded by a slight depression 2 to 5 feet deep, beyond which the land soon rises 10 to 15 feet above the beach. The material of the beach is gravel, containing pebbles up to 2 or 3 inches in diameter, but all the surface elsewhere on each side is till.

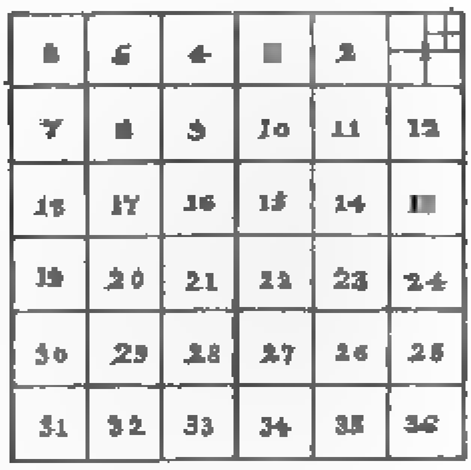

FIG. 2. Map of a township, showing its division in sections.

Beach in Secs. 30 and 32, T. 126, R. 46 (Croke), passing southeastward near the southeast corner of Sec. 30, 1,066 to 1,067 feet.

Beach near the middle of Sec. 9, T. 125, R. 46 (Tarrah), 1,057 feet. Its contour and material and those of the adjoining areas are nearly the same as at the locality already described. The width of the gravel beach here is 25 or 30 rods; the smoothed surface of till which descends thence northward is 10 to 20 feet lower in its first mile; on the south the sheet of till is at first for 40 or 50 rods about 5 feet lower than the top of the beach, but beyond this it gradually rises to a height 10 to 25 and 50 feet above the beach. The average height of its moderately undulating surface, 6 miles to the south at Graceville, is nearly represented by the railroad at the depot there, 1,107 feet.

[1] The townships herein referred to are numbered north from the base line, and the ranges are numbered west from the fifth principal meridian. The method of numbering the sections is shown by Fig. 2, above.

Beach at Dennis W. O'Brien's house, in the SW. ¼ of Sec. 11, T. 125, R. 46, 1,061 to 1,062½ feet. Northward from O'Brien's, as far as the view reaches, across T. 126, R. 46 (Croke), and T. 126, R. 45 (Doleysmount), Lake Agassiz was very shallow, the smooth and nearly level surface of till being 1,045 to 1,035 feet above the sea.

For the next 3 miles eastward the beach is less conspicuous than usual. In the northwest part of Sec. 8, the SE. ¼ of Sec. 5, and through the middle of Sec. 4, T. 125, R. 45 (Leonardsville), this shore line is again distinctly marked by a slight terrace in the till, descending northward in a moderately steep slope 5 to 10 feet, rather than by the usual accumulation of gravel. The top of this terrace is at 1,056 to 1,057 feet. The house of Patrick Leonard is built upon the edge of this terrace at the middle of the east side of section 4.

Beach, low gravel ridge 20 rods wide, 5 feet high above adjacent level, in the southeast part of Sec. 24, T. 126, R. 45 (Doleysmount), 1,060 to 1,061 feet.

These determinations indicate that in Traverse County the surface of Lake Agassiz, during its maximum stage, was very nearly 1,045 to 1,055 feet above our present sea level.

In the northwest corner of Stevens County this upper or Herman beach is well displayed in the NW. ¼ of Sec. 19, T. 126, R. 44 (Eldorado), having an elevation of about 1,063 feet. Through Sec. 18 it is 20 to 25 rods wide, with its crest at 1,063 to 1,066 feet, being a gently rounded ridge of sand and gravel, containing pebbles up to 2 or 3 inches in diameter. Its height is 7 to 10 feet above the land next west and 5 feet above the depression next east. The surface on each side is till, slowly falling westward and rising eastward.

In the southeast part of Sec. 7, same township, the crest of the beach is at 1,067 to 1,070 feet. Here and onward the next two miles, through the NW. ¼ of Sec. 8, the southeast part of Sec. 5, and the western and northern part of Sec. 4, this formation is finely exhibited in a ridge of gravel and sand 20 to 30 rods wide, 15 feet or more above its base westward, where lay the glacial Lake Agassiz, and 8 to 10 feet above the depression eastward, which divides it from the higher, moderately undulating expanse of till beyond. In the east part of Sec. 5 its elevation is 1,065 feet, and through Sec. 4, 1,065 to 1,072 feet.

Sill of Ezra S. Dunning's house, Sec. 3, T. 126, R. 44 (Eldorado), 1,074 feet.

Water in the South Branch of Mustinka River, 5 feet deep, in the NW. ¼ of Sec. 34, T. 127, R. 44 (Logan, Grant County), 1,053 feet.

Upper or Herman beach, in the northwest part of Sec. 27, same township, 1,067 to 1,069 feet; in the SW. ¼ of Sec. 22, 1,067; in the north part of this Sec. 22 and the south part of Sec. 15, forming a broad, smoothly rounded gravel ridge, 1,068 to 1,071 feet.

This beach near the middle of Sec. 15, a third of a mile southwest from Dr. C. O. Paquin's, about 30 rods wide, with a broad, nearly flat

top, 1,070 feet, having a descent of about 15 feet on its northwest side to the area of Lake Agassiz and half as much on the southeast, the surface thence rising very gradually in the 1½ miles eastward to Herman. The beach ridge is gravel; the land at each side, till.

Beach, equally well exhibited, close to Dr. Paquin's house, at the southeast corner of Sec. 10 and in the southwest part of Sec. 11, same township, 1,069 to 1,071 feet; and in this Sec. 11, at the railroad, and for 50 rods southwestward, 1,064 to 1,066 feet.

Depression, 40 rods wide, next southeast at the railroad (lowest 20 rods from the top of the beach), 1,060 to 1,063 feet.

Surface of till at the southeastern snow fences of the railroad, about a third of a mile southeast from the beach, 1,073 feet; at the northwest end of the northwestern snow fences, about 25 rods northwest from the highest part of the beach, 1,054 feet; and at the one hundred and eightieth mile post, about a quarter of a mile northwest from the last, 1,049 feet.

Saint Paul, Minneapolis and Manitoba Railway, Breckenridge division, track at Herman, 1,070 feet; at the one hundred and eightieth mile post, 1,051 feet.

FROM HERMAN NORTH TO THE RED RIVER.

Joseph Moses's house, floor of piazza, in the SW. ¼ of the NW. ¼ of Sec. 18, T. 128, R. 43 (Delaware), 1,067 feet; upper or Herman beach here, on which this house is built, 1,066 to 1,067 feet.

H. D. Kendall's house, at the east side of the SE. ¼ of Sec. 12, T. 128, R. 44 (Gorton), on the western slope of this beach, 1,062 feet; top of the beach ridge, about 25 rods east of Mr. Kendall's house, 1,067 feet.

Beach through the next 1½ miles north from Mr. Moses's house, along the west side of Secs. 18 and 7, T. 128, R. 43 (Delaware), 1,066 to 1,068 feet. The beach for this distance is finely exhibited, having a width of about 25 rods, rising 5 to 8 feet above the depression at its east side and 10 to 15 feet above the land west.

L. I. Baker's house sill, in the SW. ¼ of Sec. 6, same township, of same height with the top of the beach ridge, on which it is built, 1,068 feet.

Beach in Sec. 31, T. 129, R. 43 (Elbow Lake), not so conspicuous as usual, 1,066 feet; in (or near) the SW. ¼ of Sec. 19, same township, 1,070 feet; in the SW. ¼ of Sec. 18, at the house of Henry Olson, a gracefully rounded low ridge, as elsewhere, composed of gravel and sand, including pebbles up to 3 inches in diameter, 1,065 to 1,066 feet; at Mrs. John S. Ireland's, in the NW. ¼ of same Sec. 18, 1,070 feet; at Dr. J. M. Tucker's, in the NE. ¼ of the NE. ¼ of Sec. 2, T. 129, R. 44 (North Ottawa), 1,071 feet; about 1 mile north of the last, near the north side of Sec. 35, T. 130, R. 44 (Lawrence), 1,075 feet; and about 1 mile farther north, also 1,075 feet. Through nearly the whole of this distance it is a typical beach ridge of sand and gravel.

Beach about 30 rods west of M. L. Adams's house, in the NE. ¼ of Sec. 26, T. 130, R. 44 (Lawrence), 1,075 feet, being 4 feet above the

land adjoining this ridge on the east and about 10 feet above the flat land near on the west; in Sec. 23, same township, 1,076 feet; and near the south side of Sec. 10, same township, 1,069 to 1,074 feet.

Extensive sloughs or marshes occur in Sec. 36 and in Secs. 25 and 24, same township, each being about a mile long, lying on the east side of the beach ridge at Dr. Tucker's and reaching 2½ miles northward; the elevation of these above sea level is about 1,060 feet.

In the north part of Sec. 10 and the south part of Sec. 3, same township, this shore line of Lake Agassiz is not marked as usual by a gravel ridge, but by a somewhat abrupt ascent or terrace in the drift sheet of till, the elevation of the top of which, composed partly of gravel, is 1,085 to 1,079 feet; base of this terrace and land westward, consisting of till, slightly modified on the area of Lake Agassiz, 1,060 to 1,050 feet. This escarpment, the eroded shore line of the lake, passes about 40 rods west of N. S. Denton's house, at the north side of Sec. 10.

Beach in Sec. 34, T. 131, R. 44 (Western), the southwest township of Otter Tail County, near John F. Wentworth's, 1,070 to 1,075 feet; surface at Mr. Wentworth's barn, 1,072 feet.

Beach 25 rods east of Albert Copeland's house, in the SW. ¼ of Sec. 28, same township, 1,070 to 1,066 feet; where it is crossed by the old road from Fergus Falls to Campbell, near the northwest corner of this Sec. 28, 1,072 feet; through the next 2 miles north, finely developed, with nearly constant height, 1,072 feet, being 7 to 10 feet above the depression at its east side and 20 feet above the area westward, which was covered by Lake Agassiz; at Michael J. Shortell's, Sec. 9, same township, 1,073 feet; one mile farther north, 1,078 feet; and at A. J. Swift's, in the SE. ¼ of the NW. ¼ of Sec. 4, 1,076 feet. The beach at Mr. Swift's, and for half a mile farther north, is well exhibited and, as in many other places, is bordered on its east side by a narrow strip of marsh.

Beach in the SW. ¼ of the NE. ¼ of Sec. 33, T. 132, R. 44, 1,076 feet; top of large aboriginal mound, situated on the beach here, 1,082 feet; land 30 rods west, 1,060 feet; lakelet 250 feet in diameter, about an eighth of a mile northeast from the large mound, 1,051 feet.

Red River of the North, near the northeast corner of Sec. 33, T. 132, R. 44, 1,014 feet; on the line between this township and T. 132, R. 43 (Buse), 1,041 feet; at Dayton bridge, in the NE. ¼ of the SW. ¼ of Sec. 20, T. 132, R. 43, 1,064 feet, being 8 feet below the bridge. S. A. Austin's house, foundation, in the NW. ¼ of the SW. ¼ of Sec. 29, same township, 1,147 feet. Old grade for railroad at Dayton bridge, about 1,102 feet.

No noticeable delta was brought into Lake Agassiz by the Red River.

FROM THE RED RIVER NORTH TO MUSKODA.

Beach near the south side of Sec. 21, T. 132, R. 44, 1,077 feet; in this Sec. 21, an eighth of a mile north of the road from Fergus Falls to Breck-

enridge, 1,079 feet; and for the next mile north, 1,077 to 1,080 feet. This is a typical beach ridge, gently rounded, composed of sand and gravel, containing pebbles up to 3 inches in diameter; its width is 30 to 40 rods, and its height above the very flat area on its west side, which was covered by Lake Agassiz (usually somewhat marshy next to the beach), is about 15 feet. On the east there is first a depression of 4 to 6 feet, succeeded within a fourth of a mile eastward by a gentle ascent, which rises 5 to 10 or 15 feet above the beach. The material on each side of the beach is till, slightly modified by the lake on the west. It is all fertile prairie, beautifully green, or in many places yellow or purple with flowers during July and August, the months in which this survey was made. In August, 1881, no houses had been built on this beach, nor within one mile from it, along its first 11 miles north from the Red River, the first house found near the beach being in Sec. 26, T. 134, R. 45 (Akron), in Wilkin County.

Beach at a low portion, probably in the SE. ¼ of Sec. 5, T. 132, R. 44, 1,075 feet. A lake, nearly a mile long, lies on the flat lowland about one and a half miles west from this low part of the beach. The elevation of this lake was estimated at 1,055 or 1,050 feet; it is only a few feet lower than the general surface around it.

Beach, probably near the north side of this Sec. 5, 1,078 feet. On its east side here and for a half mile both to the south and north is a slough, partly filled with good grass and partly with rushes; its width is about a quarter of a mile and its elevation about 1,070 feet. The land west of the beach descends, within 1 or 2 miles, from 1,060 to 1,050 feet.

Beach a fourth of a mile north from the point last noted, 1,071 to 1,072 feet. This is a typical gravel beach, only 4 feet above the slough on the east and bordered on the west by marshy grassland, which slopes gently down 5 to 15 feet below this beach ridge.

Beach at its lowest portion for this vicinity, within a third of a mile north of the preceding and near the center of Sec. 32, T. 133, R. 44 (Carlisle), 1,070 to 1,068 feet, being only 2 feet above the marsh or slough on its east side. A railroad grade, abandoned, lies a third of a mile east of this. Beach a fourth of a mile farther north, 1,077 feet, and, about one mile north from its lowest portion, 1,075 feet, cut by a ravine, the bottom of which is nearly at 1,063 feet. This ravine is some 30 rods west of the abandoned railroad embankment. Beach a fourth of a mile north-northwest from the last, 1,077 feet.

Railroad grade where it crosses the beach, about a mile northwesterly from the ravine mentioned, 1,077 feet. Beach here, 1,076 feet, being 8 to 10 feet above the slough on its east side and having about the the same height above the marsh next to it westward. The material of the beach, shown by the railroad embankment, which is made of it along a distance of a third of a mile, is coarse gravel, with abundant pebbles of all sizes up to 6 inches in diameter, fully half of them being limestone.

Beach near the west side of Sec. 7, same township, at the west line of Otter Tail County, 1,083 feet. Here it is a smoothly rounded gravel ridge about 15 feet above the edge of the flat area that was covered by Lake Agassiz on the west and 10 feet above a marsh or slough that lies a few rods distant on its east side.

Sill of Rudolph Niggeler's house, in the SE. ¼ of Sec. 26, T. 134, R. 45 (Akron), 1,076 feet. This is on a portion of the beach extending about a third of a mile from south to north; a quarter of a mile to the north its elevation is 1,082 feet. In the northeast part of Sec. 35 and in the north half of Sec. 26 this beach is interrupted by sloughs, which take its place for a quarter of a mile.

Beach in the south half of Sec. 23, same township, 1,079 to 1,080 feet; in the NW. ¼ of this Sec. 23, 1,075 to 1,080 feet.

Through Secs. 14, 10, and 3, same township, the beach does not have its ordinary ridged form, but is mostly marked by a deposit of gravel and sand lying upon a slope that rises gradually eastward. Its elevation here is 1,075 to 1,085 feet. In the southern part of this distance, probably in the SW. ¼ of Sec. 14, the margin of the flat, somewhat marshy area that appears to have been covered by Lake Agassiz is very definite at 1,075 feet, which thus was probably the height of the lake here.

Beach in the SW. ¼ of Sec. 34, T. 135, R. 45 (Tanberg), composed of gravel, nearly flat, 25 to 30 rods wide, 1,084 to 1,087 feet, bordered by a depression of 2 to 5 feet on the east and by an expanse 10 to 15 feet lower on the west.

Beach in the NW. ¼ of this Sec. 34, 1,084 to 1,087 feet. Here the land next east does not present the usual slight hollow dividing the beach ridge from the higher land eastward; instead is a springy belt, mostly 1,089 feet, quite marshy, yet slowly rising 2 to 4 feet above the belt of beach gravel. Occasional hummocks, about 2 feet above the general surface and covered with rank grass about 6 feet high, form part of this belt of marsh and shaking bog. Next to the east is a slough about 1,086 feet, or 3 feet below the springy tract; and this is succeeded by a surface of moderately undulating till, which rises gradually eastward.

Martin E. Renkliv's house sill, in the SW. ¼ of Sec. 22, same township, 1,094 feet. Shore line of Lake Agassiz, an eighth of a mile west of Mr. Renkliv's, on the border of a marshy flat area, not marked by any distinct gravel ridge, about 1,075 feet.

Sloughs, mostly filled with rushes and having areas of water all the year, occupy a width of 1 to 2 miles next west of the shore line and beach of Lake Agassiz and extend nearly continuously 10 miles from south to north from the middle of T. 134, R. 45 (Akron), to the south edge of T. 136, R. 45 (Prairie View). The elevation of this belt of sloughs is 1,080 to 1,050 feet, being considerably lower on its west than on its east border. The highest land westward in the west edge of T. 135, R. 45 (Tanberg), between these marshes and Manston, is about 1,060 feet. Along most of this distance the ordinary beach ridge is wanting.

Saint Paul, Minneapolis and Manitoba Railway, Fergus Falls division, track at Lawndale water tank, in or near the southeast corner of Sec. 33, T. 136, R. 45 (Prairie View), 6 miles northwest from Rothsay and 8 miles southeast from Barnesville, 1,088 feet. Here a sidetrack has been laid, extending about a third of a mile northward, with its northern end some 50 rods east of the main line, to take ballast from the beach, which is well exhibited here and onward, having its typical ridged form. The elevation of its crest is 1,091 to 1,094 feet. It is composed of gravel and sand in about equal amounts, interstratified mainly in level layers, but with these often obliquely laminated. Most of the gravel is quite fine, and the coarsest gravel found here has pebbles only 2 to 3 inches in diameter. About half of it is limestone.

Beach ridge, 1 mile farther north, 1,094 feet; three-fourths of a mile north of the last and close south of a ravine, 1,099 feet.

Beach about 3 miles north from Lawndale water tank, probably in the south part of Sec. 16, T. 136, R. 45 (Prairie View), not ridged, but a belt 25 rods wide, of gravel and sand, on a slope of till that rises eastward, 1,080 to 1,102 feet. Beach, a ridge of gravel and sand, a third of a mile north from the last, 1,105 feet. The beach in Sec. 9 of this township is spread more broadly than usual, its higher parts being 1,095 to 1,107 feet. Here the beach deposits are crossed obliquely by several broad depressions 10 to 15 feet deep, running south-southwest. The depression east of all these banks of gravel and sand is about 1,090 feet above the sea.

Beach, a well marked ridge of gravel of the usual character, in the SW. ¼ of Sec. 4, same township, 1,096 to 1,098 feet, and at John Hart's house, in the NW. ¼ of this Sec. 4, 1,103 feet.

Entering Clay County, the elevation of this upper or Herman beach at the east side of Sec. 33, T. 137, R. 45 (Humboldt), is 1,100 feet above the sea. The land thence for two-thirds of a mile east is low and smooth, not higher than the beach. Beyond this the next third of a mile northeastward, in the north part of Sec. 34, is very rocky, with many bowlders up to 6 and rarely 10 feet in diameter, the contour being moderately rolling 10 to 30 or 40 feet above the beach. Farther eastward here and through the next 15 miles north to the Northern Pacific Railroad, the moderately rolling or smoothly hilly till rises 100 to 250 feet above this beach within the distance of about 10 miles between it and the east line of the county.

Elevation of the beach ridge in the east half of Sec. 28, T. 137, R. 45 (Humboldt), one-fourth to three-fourths of a mile south of Willow River, 1,098 to 1,100 feet. In the 3 miles westward to Barnesville the area that was covered by Lake Agassiz shows here and there bowlders projecting 1 to 2 feet above the surface, which is till, slightly smoothed by the lake.

Saint Paul, Minneapolis, and Manitoba Railway, track at Barnesville, 1,097 feet.

The beach for three-fourths of a mile north from Willow River consists of a belt of gravel and sand, lying on an eastwardly ascending slope of till. Through the next 1½ miles northward, in the NW. ¼ of Sec. 22 and in Sec. 15, T. 137, R. 45 (Humboldt), the shore of Lake Agassiz is not marked by the usual beach of gravel and sand, but instead becomes a belt of marshy and springy land 20 to 50 rods wide, rising by a gentle slope eastward, rough with many hummocks and hollows, in some portions forming a quaking bog, in which horses and oxen attempting to cross are mired.

In the next 2 miles northward, through Secs. 10 and 3, same township, the beach is nowhere well marked as a ridge, but is mainly a belt of gravel and sand, lying on a slope of till, which gradually rises 30 or 40 feet higher at the east. The lack of typical beach deposits on this shore through the north half of this township is probably due to its sheltered situation in the lee of islands on the northwest. The course of the shore currents, determined by the prevailing winds, seems to have been southward, as on the shores of Lake Michigan.

Highest part of southern island in the east edge of Lake Agassiz, in the NE. ¼ of Sec. 5, T. 137, R. 45 (Humboldt), extending northward into T. 138, R. 45 (Skree), 1,117 to 1,122 feet. This island was about a mile long from south to north. Beach on its west side, a well developed ridge of gravel, near the middle of the north line of Sec. 5, 1,095 feet; and for a third of a mile north-northwest from this, 1,094 to 1,096 feet. On the east side of the beach, as it continues northward, is a slough two-thirds of a mile long from south to north and about 30 rods wide, 1,085 feet. This was evidently filled by a lagoon, sheltered on the southeast by the island and separated from the main lake by the beach. Toward the northeast it widened into a shallow expanse of water, 8 to 15 feet deep, about 1½ miles wide, divided from the broad lake on the west by two islands and this beach, or bar, which connected them. Lake Agassiz here appears to have stood at the height of 1,090 to 1,095 feet.

Beach or bar in the north part of Sec. 32, T. 138, R. 45 (Skree), a broad rounded ridge of gravel, with pebbles up to 3 or 4 inches in diameter, 1,103 feet, and through the next half mile, in the south half of Sec. 29, 1,102 to 1,104 feet. Along part of this distance the beach ridge is bounded eastward by a steeper descent than usual, the land next east being 1,085 to 1,090 feet above the sea. This beach or bar continues northward in a typical ridge through Secs. 29 and 20, same township.

Beach or bar at L. Williams's house, in the SW. ¼ of the SE. ¼ of Sec. 20, same township, 1,101 feet; a quarter of a mile farther north, 1,106 feet; three-quarters of a mile north of Mr. Williams's, near the middle of the north line of Sec. 20, 1,110 feet, continuing a very definite ridge through the south half of Sec. 17, 1,109 to 1,110 feet.

Near the middle of this Sec. 17 the beach deposit of gravel and sand ceases at the west side of the northern island, which was situated in

the east half of this section and extended also eastward in a long, low projection nearly across the south side of Sec. 16, and northward half way across Sec. 8. Highest part of this island, in or near the NE. ¼ of the NW. ¼ of Sec. 17, about 1,125 feet. The old shore of the north half of this island has no beach ridge nor other deposits of gravel and sand, but is plentifully strewn with large bowlders up to 5 and 10 feet in diameter, and many of these project 2 to 5 feet above the general surface. The lake waves eroded here and deposited the sand and gravel gathered from this till as a beach a little farther south.

North and northeast from this northern island a lower expanse, nearly level and in some portions marshy, resembling the broad flat valley of the Red River, extends 1½ miles to the east shore of Lake Agassiz, its height being 1,075 to 1,090 feet, or 10 to 25 feet below the surface of the ancient lake. The distance between these islands was 2 miles, and the distance from the summit of the first to that of the second, nearly due north, 4 miles. Each of them rose about 25 feet above Lake Agassiz. The strait between them and the mainland eastward was 10 to 20 feet deep and from 1 to 1½ miles wide, excepting a narrow place near the southeast corner of Sec. 16. East of the northern island the main shore of the lake was indented by a bay a third to a half of a mile wide and about 10 feet deep, stretching 2½ miles southeastward from the lake at the northwest corner of Sec. 10 to the west part of Sec. 23, same township. The shore of the lake east of its islands along this bay and northwesterly to the north line of this township lacks the beach deposits which elsewhere distinguish it.

In its continuation northwestward the shore line of the old lake runs diagonally across Sec. 32, T. 139, R. 45 (Hawley), where it again presents the anomalous character of a very springy and marshy belt, 20 to 40 rods wide, rough with hummocks and in many places so deeply miry that it is dangerous for teams. This boggy tract has a gentle descent westward, its lower portion being about 1,085 feet, and its upper border, very nearly level across this entire section, being 1,098 to 1,100 feet, which was almost exactly the height of Lake Agassiz, as shown by its distinct beach of gravel and sand at the south and north. Next eastward rises a moderately undulating slope of till, strewn with abundant bowlders; and rarely a bowlder, 2 to 5 feet in diameter, is seen on the springy land that marks the border of the ancient lake.

DELTA OF THE BUFFALO RIVER.

The delta brought into the east side of Lake Agassiz by the Buffalo River extends about 5 miles southwestward from Muskoda, forming a continuously descending plain of stratified sand and fine gravel, declining from 1,100 feet near Muskoda to 1,073 feet at its southwestern limit in the north part of Sec. 34, T. 139, R. 46 (Riverton). Here and northward along a distance of 3 miles to the Buffalo River, this delta

plain is terminated by a steep slope like the face of a terrace; the outer portion of the original delta, beyond this line, has been carried away by the waves and shore currents of the lake when it stood at the lower level marked by the Norcross beach.

Northern Pacific Railroad, track at Muskoda, 1,090 feet. Threshold of church a quarter of a mile southeast from Muskoda depot, 1,113 feet. Beach here and for a third of a mile south to the Buffalo River, as also at the excavation for the railroad, 25 rods north of the church, 1,113 to 1,114 feet. The beach here is 35 rods wide, rising 14 or 15 feet in a gentle swell above the edge of the delta of modified drift on the west and descending the same amount to the depression at its east side. It is made up of interstratified gravel and sand, the former prevailing, including pebbles up to 3 or 4 inches and rarely 6 or even 9 inches in diameter, all water-worn. Half or two-thirds of these pebbles are limestone. No bowlders occur here, nor are they found in any of the beach deposits of Lake Agassiz.

FROM MUSKODA NORTH TO THE WILD RICE RIVER.

Beach in the next 2 miles north of Muskoda, mainly 1,113 to 1,125 feet; at its lowest depression, about 1 mile north of Muskoda, 1,105 feet; at William Perkins's house, in the SE. ¼ of the SE. ¼ of Sec. 30, T. 140, R. 45 (Cromwell), 1,122 feet; an eighth to a third of a mile south-southeast from Mr. Perkins's, 1,130 feet. A nearly or quite continuous depression, from a fifth to a third of a mile wide, lies at the east side of this beach, declining in elevation from 1,118 feet, near Mr. Perkins's house, to 1,100 feet at Muskoda. This distance is about 3 miles.

The surface of Lake Agassiz in its maximum stage was at Muskoda 1,105 feet very approximately above our present sea level. Within 5 to 10 miles northward, its height seems to have been 1,110 to 1,115 feet.

Beach through the north half of Sec. 30, T. 140, R. 45, 1,128 to 1,131 feet, and through the west part of Secs. 19 and 18, same township, 1,125 to 1,130 feet, composed of sand and fine gravel, not generally in a typical ridge, but often with a depression 2 to 5 feet lower eastward and bounded on the west by a descent of about 30 feet within an eighth of a mile. A surface of slightly undulating till rises very gradually from this beach eastward.

In T. 139, R. 46 (Riverton), and in Secs. 35 and 26, T. 140, R. 46, the eroded western border of the delta of Buffalo River marks the shore of Lake Agassiz at the time of the Norcross beach.

In the west part of Sec. 24, T. 140, R. 46, and for 4 miles northward, the Norcross beach lies only 1 mile to a half mile west of the upper beach and is about 50 feet lower. The terracelike area between these beaches is strewn with occasional bowlders up to 6, 8, or 10 feet in diameter and rarely of larger size, much more abundant than upon the average surface of the till in this region, indicating that the surface

there has been considerably eroded by the waves of the lake. The largest bowlder seen in Clay County lies about 50 rods west of the upper beach, in or near Sec. 12, T. 140, R. 46. Its dimensions are 15 by 12 by 5 feet and its top is 1,095 feet above the sea. It is gneiss, minutely porphyritic, with white feldspar crystals up to an eighth or a quarter of an inch long.

The elevation of the foot of the western slope of the upper or Herman beach along the north part of the east line of T. 140, R. 46, is 1,095 to 1,100 feet. Crest of the Norcross beach in Sec. 12, T. 140, R. 46, 6 miles north of Muskoda, 1,080 feet, and along the distance of 3 miles through Secs. 13, 12, and 1, it varies from 1,075 to 1,085 feet. In Sec. 31, T. 141, R. 45 (Keon), its height is 1,085 feet. Like the Herman beach, it is a low, smoothly rounded ridge of gravel and sand, usually having a depression of 3 to 5 feet or more at its east side.

Upper or Herman beach at a high portion in or near the SE. ¼ of Sec. 1, T. 140, R. 46, 1,136 feet. For a mile next south from this point, it is a finely rounded ridge of gravel rising northward from 1,130 to 1,136 feet. The depression at its east side is 4 to 6 feet lower; then the surface gently rises at a quarter to a third of a mile from the beach to 1,135 or 1,140 feet, beyond which eastward this nearly level but slightly undulating expanse of till rises only 5 or 10 feet a mile.

Beach a fourth of a mile north-northeast from the high point mentioned, probably in the NW. ¼ of Sec. 6, T. 140, R. 45 (Cromwell), 1,128 to 1,127 feet. This is an ordinary beach ridge of gravel and sand, with a depression of 2 or 3 feet next east.

Near the south line of Sec. 29, T. 141, R. 45 (Keon), both the Herman and Norcross beaches, here about two-thirds of a mile apart, are intersected by a watercourse. At its north side the upper or Herman beach, near the east line of Sec. 29 and in the NW. ¼ of Sec 28, consists of two well marked ridges of gravel and sand, some 30 rods apart and about 10 feet above the land eastward and between them. These ridges unite in or near the SW. ¼ of the SW. ¼ of Sec. 21, at the height of 1,130 to 1,132 feet.

Beach three-fourths of a mile farther north, probably near the north line of Sec. 21, a typical gravel ridge, 1,134 feet, 10 feet above the land next east; but a sixth of a mile farther northeast this beach ridge is depressed to 1,123 feet.

A lower beach, contemporaneous with the Herman beach farther south, but formed when the surface of the lake in this latitude had fallen slightly from its highest level, is finely exhibited, at a distance of one-third to two-thirds of a mile west from the upper beach, through the 4 miles from the south side of Sec. 20 to the northeast corner of Sec. 4, same township. The elevation of this secondary beach in the south part of Sec. 20 is 1,115 feet; thence to a stream near the east line of the SE. ¼ of Sec. 17, 1,118 to 1,123 feet; at each side of this stream, 1,118 feet;

northward, in the northwest part of Sec. 16 and in the SW. ¼ of Sec. 9, 1,118 to 1,121 feet; and in the north part of Sec. 9, 1,121 to 1,127 feet.

The elevation of the upper beach in T. 141, R. 45 (Keon), 1,123 to 1,137 feet, shows that the height of Lake Agassiz here, during its maximum stage, was about 1,120 feet. The secondary beach was made by the lake after it had fallen 6 to 10 feet.

Surface of ground at Christian Sether's house, in the SW. ¼ of Sec. 10, 1,129 feet. Upper beach through the west part of this Sec. 10, 1,130 to 1,137 feet, increasing in height from south to north. This is a typical beach ridge of gravel, with a rather abrupt descent on its east side to land 6 or 8 feet lower, which thence ascends with a slightly undulating surface eastward.

Upper beach in Sec 3, same township, 1,134 to 1,137 feet, 10 feet above the land next east. Secondary beach, parallel with this and about three-fourths of a mile distant to the northwest, in Secs. 4 and 34, 1,123 to 1,127 feet, being thus 10 feet lower than the highest parts of the eastern beach. Extensive sloughs, inclosing lakelets, lie between these beaches in Secs. 34 and 35, T. 142, R. 45 (Hagen), at an elevation of 1,115 to 1,120 feet, but sinking northward to 1,105 feet. The secondary beach continues to the northeast corner of Sec. 26, declining in height northeastward as it approaches the South Branch of the Wild Rice River, being at 1,125 to 1,115 feet.

Upper beach in Sec. 35 and in the south part of Sec. 25, T. 142, R. 45, 1,140 to 1,142 feet. This is a typical beach ridge of sand and gravel, about 30 rods wide, with the land next southeast 5 to 8 feet lower, and divided from the secondary beach northwesterly by a slough about 1 mile wide, this slough being at 1,115 to 1,105 feet.

Beach at B. O. Helde's house, in the south half of the SW. ¼ of Sec. 30, T. 142, R. 44 (Ulen), 1,138 feet. The flat expanse of the Red River Valley reaches east on the South Branch of the Wild Rice River to Sec. 16, T. 142, R. 45 (Hagen), probably being there about 975 feet above the sea, or 160 feet below this upper beach of Lake Agassiz, 4 or 5 miles southeast.

Beach through Secs. 30 and 29, T. 142, R. 44 (Ulen), extending 1½ miles east-northeast from Mr. Helde's to the South Branch of the Wild Rice River, in a low, gently rounded ridge of gravel, 30 rods wide, 5 to 8 feet above the area of till next southeast and about 15 feet above the surface close at its northwest side, 1,138 to 1,142, mostly 1,140, feet.

Beach at Nels Wiger's house, probably in the NW. ¼ of Sec. 28, 1,133 feet; about 40 rods west from this, 1,140 feet.

South Branch of Wild Rice River, in the SW. ¼ of Sec. 21, same township, 1,095 feet.

Beach, a typical gravel ridge, in or near the west half of Sec. 16, a half mile to 1½ miles north of the South Branch, 1,140 to 1,143 feet; surface of till an eighth to a quarter of a mile next east, 1,135 feet. Farther east the slightly or moderately undulating expanse of till has

an average ascent of about 10 feet a mile for 15 miles to the base of the high land at the White Earth Agency, which is dimly visible, blue, close to the horizon. Westward the surface gradually descends to the Norcross beach, nearly 60 feet lower, which is the farthest land in sight in that direction, about 3 miles distant, beyond which lies the flat Red River Valley.

Beach, a well defined ridge, in Secs. 9 and 4, T. 142, R. 44 (Ulen), 1,139 to 1,144 feet.

Entering Norman County, an unusually high portion of the beach is found in or near the SE. ¼ of the SE. ¼ of Sec. 33, T. 143, R. 44 (Home Lake), having its crest at 1,149 feet. It holds this elevation for an extent of some 20 rods, on each side of which its height is mostly from 1,139 to 1,145 feet. Its material is coarse gravel, principally limestone, with pebbles up to 4 and 6 inches in diameter. Surface close east of this beach, 1,137 feet. A slight swell above the general descending slope westward, about 2 miles distant, has a height very nearly 1,125 feet. This may be the continuation of the secondary beach that was seen in T. 141, R. 45 (Keon). It hides the view farther west, except from the highest point of the beach (1,149 feet), where the distant belts of timber along the Red and the Wild Rice Rivers are visible.

Beach at J. T. Huseby's house, in the SW. ¼ of the NW. ¼ of Sec. 26, T. 143, R. 44 (Home Lake), 1,147 feet; through 1¼ miles next north, in the NW. ¼ of Sec. 26 and the west part of Sec. 23, forming a broad, low ridge of gravel and sand, 1,145 to 1,149 feet.

In or near Secs. 17 and 16, T. 143, R. 43 (Flom), a prominent massive hill, called "Frenchman's Bluff," of somewhat irregular form, composed of morainic till, rises 150 feet or more above this beach.

Through the W. ½ of the NW. ¼ of Sec. 14, T. 143, R. 44 (Home Lake), the beach is mostly a typical gravel ridge, with its crest at 1,147 to 1,152 feet. In the NW. ¼ of Sec. 11, same township, it curves northeastward and attains an unusually massive development, its crest being at 1,150 to 1,158 feet, rising 15 feet above the land next southeast and 30 feet above the border of the area of Lake Agassiz at its northwest side.

Beach, a well marked gravel ridge near the southwest corner of Sec. 1, same township, 1,156 feet, and an eighth of a mile east-northeast from this, 1,150 feet.

J. G. Aurdal's house, foundation, in the NW. ¼ of the NE. ¼ of Sec. 6, T. 143, R. 43 (Flom), 1,148 feet. This is situated on the beach, which here is a deposit of gravel and sand 8 feet or more in depth, lying upon a slope of till that ascends southeastward.

Anton Johnson's store, foundation, on this beach, in the SE. ¼ of the SE. ¼ of Sec. 31, T. 144, R. 43 (Fosum), 1,142 feet.

Creek flowing northwesterly between the last two, about 1,105 feet.

Wild Rice River, 2 miles north of Johnson's store, approximately 1,075 feet.

Secondary Herman beach, a well marked, broad, smoothly rounded gravel ridge, extending from southwest to northeast, crossed by the township line road at the north side of the NE. ¼ of the NW. ¼ of Sec. 2, T. 143, R. 44 (Home Lake), 1,137 feet. It is about 30 rods wide and rises 5 to 10 feet above the depression at its southeast side.

FROM THE WILD RICE RIVER NORTH TO MAPLE LAKE.

A broad belt of timber borders the Wild Rice River, lying mostly on its north side, in T. 144, R. 43 (Fosum), and T. 144, R. 44 (Wild Rice), and at the time of this survey, in 1881, no road nor bridge afforded a crossing here. Therefore this series of levels was resumed north of the Wild Rice River by starting from Rolette Station of the Saint Paul, Minneapolis and Manitoba Railway, 890 feet above the sea, near the middle of Sec. 17, T. 146, R. 46 (Lockhart), about 1½ miles north of the Lockhart farm. Proceeding eastward from this point, the first observations of the upper beach were in T. 145, R. 43 (Waukon); T. 146, R. 44 (Sundal); and T. 147, R. 44 (Garfield).

This beach is intersected by the Wild Rice River near the middle of T. 144, R. 43 (Fosum), and thence it passes north-northwesterly through the west part of T. 145, R. 43 (Waukon). In Secs. 7 and 6, same township, it is a low smooth ridge of gravel and sand about 25 rods wide, rising 5 to 10 feet. In the west half of this Sec. 6 and in Sec. 36, T. 146, R. 44 (Sundal), the old Pembina trail lies on it.

About 2 miles west of the upper beach, a secondary Herman beach, of similar material and contour, probably 20 feet lower, was observed a few rods east of the stake at the middle of the north side of Sec. 14, T. 145, R. 44 (Strand), having a height of 6 to 8 feet above its base, with a smaller ridge of sand and gravel, 3 feet high above its base, close west of this stake. Again, a half mile farther west, in the northeast corner of Sec. 15, same township, another Herman beach, probably 10 feet below the last, was noted, having a height of 4 or 5 feet above its base.

Traveling northwestward along the Pembina trail, the upper beach ridge was not distinctly observed after leaving Sec. 36, T. 146, R. 44 (Sundal), until it is again occupied by the trail in Sec. 9 of this township. The intervening 3 miles are flat and nearly level. Probably the beach, less noticeable than usual, lies within a half or 1 mile east of the trail here. In the eastern part of Sec. 9 this beach is about 25 rods wide, rising 5 feet from its east side and descending 10 feet to its western base, which was the margin of Lake Agassiz.

Thence the upper beach extends nearly due north through the east edge of Sec. 4, same township, and Sec. 33, T. 147, R. 44 (Garfield). In the east edge of the SE. ¼ of Sec. 28 and the west edge of the NW. ¼ of Sec. 27, T. 147, R. 44, it is a typical ridge of gravel and sand, with its crest 1,166 to 1,173 feet above the sea. There is a gradual descent toward the west. The depression on the east is a sixth to a fourth of a mile wide,

sinking 6 to 10 feet below the beach. Farther eastward the land is moderately undulating till, rising 20 to 30 feet above the beach and bearing frequent groves of small poplars, bur oak, and canoe birch.

Water in Sand Hill River, at the ford of the old Pembina trail, in the west part of Sec. 28, T. 147, R. 44, ordinary low stage, July 26, 1881, 1,071 feet.

Even Grödvig's house threshold, at the top of the bluff north of this ford, in the north half of the NW. ¼ of this Sec. 28, 1,136 feet.

When Lake Agassiz stood at its greatest height, the Sand Hill River brought into its margin a delta 6 miles long from south to north and 3 miles wide, reaching from the upper beach to the west side of T. 147, R. 44 (Garfield), and T. 146, R. 44 (Sundal). This westwardly sloping deposit of stratified gravel and sand has about an equal area and thickness with the delta of the Buffalo River at Muskoda. Upon this delta plain dunes have been heaped up by the winds, probably before vegetation had spread over this area after the withdrawal of the glacial lake.

In the south half of Sec. 32, T. 147, R. 44 (Garfield), and in a belt which thence extends approximately north and south, the sand of this delta, as originally deposited, rises eastward with a slope of 25 or 30 feet in 1 mile, from 1,100 to 1,125 or 1,130 feet above the sea. Beneath this plane, however, channels have been eroded by the winds and sand-hills 25 to 75 feet above it have been blown up in irregular groups and series, scattered over a tract about a mile wide and extending 3 or 4 miles southward from the Sand Hill River, in Sec. 29, the northeast part of Sec. 30, and in Secs. 31 and 32, T. 147, R. 44 (Garfield), and reaching southward in Secs. 5 and 8, T. 146, R. 44 (Sundal). The most southern of these hills is an isolated group in the east part of the NE. ¼ of Sec. 18, T. 146, R. 44 (Sundal). Another isolated group lies north of the Sand Hill River, in the NW. ¼ of Sec. 16, T. 147, R. 44 (Garfield). These sand dunes are in part bare, being so frequently drifted by the winds as to allow no foothold for vegetation; other portions are clothed with grass or with bushes and scanty dwarfed trees, including bur oak, the common aspen or poplar, cottonwood, green ash, black cherry, and the frost grape.

Elevations of the highest points of these dunes, in order from south to north, are approximately 1,190, 1,180, and 1,200 feet. The highest dune appears to be in or near the east half of the NE. ¼ of Sec. 30, T. 147, R. 44 (Garfield).

Secondary Herman beach, a smoothly rounded ridge of gravel and sand 10 to 15 feet high above the adjacent level, 1,148 to 1,153 feet above the sea, about three-fourths of a mile east of the old Pembina trail, in the west half of Secs. 21 and 16, T. 147, R. 44 (Garfield), extending 1½ miles north from the Sand Hill River to the cluster of dunes in the NW. ¼ of Sec. 16.

Upper Herman beach, the first of the series which was here formed contemporaneously with the single Herman beach farther south, run-

ning approximately from south to north through or near the northeast corner of Sec. 4, T. 147, R. 44 (Garfield), a smooth gravel ridge, in some parts hidden by scattered groves, 1,165 to 1,175 feet. Farther east is a large area of woodland. Second Herman beach, in the east part of Sec. 5, same township, and Sec. 32, T. 148, R. 44 (Godfrey), about a mile west from the upper beach, 1,149 to 1,153 feet; this is a ridge of gravel and sand, about 40 rods wide, with very gentle, prolonged slopes toward both the east and the west. Natural surface at the northeast corner of Sec. 32, T. 148, R. 44 (Godfrey), 1,146 feet. Third Herman beach, running north, in the NW. ¼ of Sec. 5, T. 147, R. 44 (Garfield), and the west part of Sec. 32, T. 148, R. 44 (Godfrey), a half or two-thirds of a mile west from the last, 1,130 to 1,135 feet, consisting of a distinct ridge in its southern part, but farther north being a flat area of gravel and sand slightly elevated above the land next east.

Second Herman beach, a broad low ridge of gravel and sand, extending north-northeast through Sec. 28, T. 148, R. 44 (Godfrey), from its southwest corner to its north line, 1,148 to 1,150 feet. The northward continuation of this beach is a low, flattened ridge, the western one of two parallel ridges of gravel below that of the upper beach, extending northeasterly and northerly through or near the west edge of Sec. 10, same township, 1,150 to 1,154 feet. Through the next 3 miles in Sec. 3, same township, and in the east part of Secs. 35 and 26 and the NW. ¼ of Sec. 25, T. 149, R. 44 (Tilden), it is a prominent beach ridge, with its crest at 1,153 to 1,161 feet, somewhat steep on its east side, which descends about 10 feet to a belt of lowland and marsh that divides it from the parallel beach a quarter to a third of a mile east.

The eastern of these parallel beach ridges is only 8 or 10 feet below the average elevation of the upper beach. It probably marks a slight fall in the water surface at this latitude; but, as no corresponding beach formation has been observed in Dakota, it is neglected in the foregoing table of elevations of the beaches of Lake Agassiz. It is clearly continuous 8 miles, the first 4 miles extending northerly and the next 4 miles easterly. These parts are connected in Sec. 25, T. 149, R. 44 (Tilden), by a graceful curve, that portion of this beach and its extent thence eastward being known as the "Attix ridge," from Henry and William Attix, brothers, who have built their houses upon it. In its northward course, nearly through the middle of Secs. 10 and 4, T. 148, R. 44 (Godfrey), its crest is at 1,158 to 1,163 feet; in the west edge of Sec. 36, T. 149, R. 44 (Tilden), and along its curved course to the northeast and east at the west and north sides of Sec. 25 and in the southeast part of Sec. 24, same township, 1,163 to 1,168 feet, and in Secs. 21 and 22, T. 149, R. 43 (Grove Park), 1,171 to 1,173 feet. Slough, a third to a half of a mile wide, extending along the east side of this beach, in Sec. 3, T. 148, R. 44 (Godfrey), and in the southeast part of T. 149, R. 44 (Tilden), 1,155 to 1,160 feet.

Upper beach in the SW. ¼ of Sec. 11, T. 148, R. 44 (Godfrey), forming a plain of stratified gravel and sand a quarter or a third of a mile wide from east to west, 1,168 to 1,173 feet. This beach near the south side of Sec. 11 becomes a distinct gravel ridge of the usual character, about 25 rods wide, with its crest at 1,173 feet, bordered by a slough 20 to 40 rods wide at its east side. About a third of a mile farther southeast and some 50 rods west of the southwest extremity of Maple Lake, in Sec. 14, same township, the elevation of this beach ridge is 1,175 to 1,178 feet.

Maple Lake, water surface July 28, 1881, 1,169 feet.

Upper beach, top of its well marked gravel ridge in the east edge of the NE. ¼ of the NE. ¼ of Sec. 3, T. 148, R. 44 (Godfrey), about 20 rods north of Mr. Horton's, 1,180 feet.

Beyond this point, through its next 2½ miles, curving from a northward to a northeastward and eastward course, this upper beach of Lake Agassiz is magnificently exhibited, forming a massive, gently rounded ridge of gravel and sand about 30 rods across, with its crest 1,178 to 1,186 feet above the sea. It is bordered on its southeast side by a tract of slightly undulating till 10 to 15 feet lower, mostly covered with small timber and brush and holding frequent sloughs and lakelets in its depressions. The top of the beach is not wooded, but small trees and bushes encroach upon its slopes. A road extends along the crest of its curving portion for a distance of about 1 mile through Sec. 36, T. 149, R. 44 (Tilden).

The marsh which borders the northwest side of the northeast part of Maple Lake shows a descent of 5 to 7 feet northwestward, or away from the lake, in its width of 1 to 1½ miles Maple Lake is prevented from flowing in this direction by a beaver dam near the lake. Creek draining this marsh where it intersects the upper beach near the east line of the NE. ¼ of Sec. 27, T. 149, R. 43 (Grove Park), 1,163 feet. Here the beach skirting the north side of the marsh is a flat deposit of gravel and sand, a fourth to a half of a mile or more in width, highest next to the marsh, above which it rises 5 to 8 feet in a moderate slope. Its elevation in the north half of Secs. 26 and 27 is 1,169 to 1,172 feet, being even 1 or 2 feet lower than the Attix ridge, which lies some two-thirds of a mile farther north, in the south half of Secs. 21 and 22. This belt of beach gravel and sand continues 6 miles in a nearly due east course, and beyond that it extends still eastward along the north side of a great tamarack swamp, which begins in Sec. 34, T. 149, R. 42, and is said to be 8 miles long. Maple Lake and this tamarack swamp hold the same relation to the upper beach ridge, which was a barrier between them and Lake Agassiz and which now wholly or partially obstructs the drainage of these areas.

Third Herman beach, a small ridge of gravel and sand, extending from southwest to northeast, 8 to 10 rods wide and rising 4 or 5 feet, crossed by the Crookston road in the SW. ¼ of Sec. 23, T. 149, R. 44

(Tilden), and seen to reach at least a mile each way from this road, 1,146 to 1,149 feet.

Natural surface at the southeast corner of Sec. 15, same township, 1,134 feet.

Fourth Herman beach, crossed by road to Crookston and Red Lake Falls near the center of the SE. ¼ of this Sec. 15, 1,132 to 1,134 feet. This is a well marked gravel ridge, mainly single, but twofold where it is crossed by this road. The distance of 1 mile here between these third and fourth Herman beaches consists of till, with a nearly smooth surface, which has bowlders up to 3 and rarely 5 feet in diameter quite numerously scattered over it. Southeastward from the third to the first or upper beach the surface mostly is modified drift, with no bowlders.

Four to five miles north from the fourth Herman beach the road to Red Lake Falls crosses the Norcross beach in Sec. 27, T. 150, R. 44 (Lake Pleasant), where it is a belt of gravel and sand about a half mile wide, extending from west-southwest to east-northeast, at an elevation of 1,083 to 1,095 feet.

THE UPPER OR HERMAN BEACH IN DAKOTA.

[See the accompanying map, Plate I.]

FROM LAKE TRAVERSE NORTHWEST TO MILNOR.

From the south extremity of Lake Agassiz, in Sec. 18, T. 125, R. 45 (Leonardsville), Traverse County, Minn., the upper or Herman beach extends northwestward 75 miles to the most southern bend of the Sheyenne River in Ransom County, Dakota, and thence its course is nearly due north, but with slight deflection westward, to the international boundary. The mouth of Lake Agassiz was where now a slough 2 to 3 miles wide, with frequent areas of open water, stretches northward from the northeast end of Lake Traverse. On the west side of this slough and of Lake Traverse bluffs of till rise 100 to 125 feet; their tops and the rolling surface of till which extends thence westward are 1,070 to 1,100 feet above the sea.

The beginning of the upper or Herman beach in Dakota is in Secs. 10, 3, and 4, T. 128, R. 48, nearly 2 miles south from the north line of the Sisseton and Wahpeton reservation. It rises with terracelike steepness 20 or 30 feet above the surface of undulating till which borders it on the northeast. Its material is sand and gravel, with pebbles up to 1½ or 2 inches in diameter, about half of which are limestone. Beyond its steep margin this deposit of beach gravel forms a belt about a mile wide, approximately level, but with frequent short swells and low flattened ridges 5 to 10 or 15 feet above the intervening depressions. Its elevation is 1,060 to 1,070 feet above the sea, or from 90 to 100 feet above Lake Traverse.

For its first 3 or 4 miles the terracelike margin of the beach sweeps with a gentle curve westerly and northerly to a point in the SW. ¼ of Sec. 34, T. 129, R. 48, where it turns quite abruptly, taking a nearly due west course for the next 3 miles to the west side of Sec. 31 of this township.

In the NW. ¼ of Sec. 3, T. 128, R. 48, a third of a mile east of W. J. Allen's house, the ascent at the beach margin is about 10 feet to an elevation of 1,060 feet, approximately. The belt of sand and fine gravel is here about a half mile wide. Occasional hummocks, rising 5 to 10 feet and 50 to 100 feet long, which were observed on this part of the beach, appear to have been heaped up by the wind before the protecting mantle of grass and other vegetation was spread over it. In the SE. ¼ of Sec. 32, T. 129, R. 48, similar dunes, 1,075 to 1,080 feet above the sea, have been excavated for use as plastering sand. Nearly all portions of this beach and even its dunes are now covered with a black soil and plentiful vegetation; but certain species preferring dry and sandy soil, as the dwarf rose, grow in greater abundance on the beach, and especially among its hummocks and hollows, than on the flat or slightly undulating surface of till at each side.

The margin of this Herman beach, marking the shore of Lake Agassiz at its maximum stage, passes in its western course about 60 rods north of the southeast corner of Sec. 32 and turns again to the northwest near the middle of the west side of Sec. 31, T. 129, R. 48. At the latter locality it is a low wavelike ridge of sand and fine gravel, about 1,060 feet above the sea. On the south it is bordered by land 3 to 5 feet lower for a width of one and a half miles. J. R. Grimesey's well, 13 feet deep, at the southwest corner of Sec. 31, on this low tract outside the beach ridge, encountered only very fine stratified sand, irregularly laminated and containing numerous tubular limonitic concretions. Farther to the southwest and west, a gently undulating surface of till, scarcely higher than the beach of Lake Agassiz, stretches away several miles, beyond which the highland of the Coteau des Prairies is seen in the far distance.

The Herman beach crosses T. 129, R. 49, in a diagonal course, entering it a half mile north of its southeast corner and running northwest to the north side of Secs. 5 and 6. In Sec. 23 and the northeast part of Sec. 22, its elevation is about 1,055 feet; but its dunes rise 3 or 4 feet higher. At the middle of the north side of Sec. 16, on the line between Roberts and Richland Counties, it is a ridge of sand and fine gravel about 8 rods wide, rising 4 to 6 feet above the land on each side. Its crest here, and for a mile to the southeast and northwest, is 1,060 to 1,065 feet above the sea. Northeastward the surface falls about 20 feet in the first mile. On the southwest side of this distinct beach ridge, a smooth, slightly undulating tract 1½ to 2 miles wide, extending through this township, consists of sand and fine clayey silt. Its elevation varies from 1,055 to 1,080 feet, attaining the latter height in

the northwest part of the township. This belt, with its continuation southeastward, previously described, was doubtless covered by Lake Agassiz before the erosion of its outlet to the level of the Herman beach; but much of its stratified sand and silt may be modified drift deposited by streams from the melting ice sheet. The glacial recession here was from southwest to northeast, and this was probably an avenue of drainage during a short time, till the continued retreat of the ice left a considerable expanse of water, the beginning of Lake Agassiz, between itself and the shore.

In the north part of Secs. 5 and 6, T. 129, R. 49, and in Secs. 31 and 32, T. 130, R. 49, this beach consists of two or three parallel wavelike ridges of gravel and sand, divided by depressions an eighth to a quarter of a mile wide and 5 to 10 feet lower.

This belt reaches north to the Lightning's (or Thunder's) Nest, a massive dune of fine sand, partly bare and now wind blown, but mostly covered with bushes and herbage, situated near the center of Sec. 30, T. 130, R. 49. Its base on the south is 1,060 feet and its top 1,120 feet, approximately, above the sea. It covers a space about a quarter of a mile in extent from southeast to northwest, with nearly as great width, and rises in two summits of nearly equal height. The Lightning's Nest is the most prominent in a series of dunes, elsewhere rising only 10 to 30 feet, mostly grassed, which extends a mile or more to the southeast and is traceable several miles northwest to the east end of a very conspicuous tract of dunes 50 to 100 feet above adjacent level, with summits at 1,100 to 1,150 feet above the sea, which stretches about 4 miles in a west-northwest course in the south part of T. 131, R. 50, 1 to 2 miles south of the Wild Rice River. By winds, eroding and drifting, these sand hills were heaped up from the Herman beach and its associated belt of modified drift, probably soon after the retreat of the ice, though their forms have been constantly changing since that time.

Outside the area of Lake Agassiz, the southwest part of Richland County is till, mostly undulating or moderately rolling, but in part prominently hilly, with rough morainic contour and abundant bowlders. Taylor Lake, approximately 1,050 feet above the sea, 2½ miles west of the Lightning's Nest, is a very beautiful sheet of water, bordered by a sandy shore and a large grove on the north and by a shore of bowlders and morainic hills 50 to 150 feet above the lake on the west. These hills and most of the lakes farther west in this county have no timber. Northeastward the area that was covered by Lake Agassiz is mostly smooth and nearly flat till, with frequent marshy tracts called sloughs, but with only very rare and small lakelets.

Swan Lake, 3 miles long, reaching from Sec. 3 to Sec. 7, T. 130, R. 51, estimated 1,070 feet above the sea, with undulating till 5 to 10 feet higher on the northeast and 10 to 20 feet higher on the south and west.

Herman beach, a ridge of fine sand, 20 to 25 rods wide and about 3 feet high, near the south line of Sec. 36, T. 132, R. 52, extending west-northwest, approximately 1,065 feet. On the north, the exceedingly flat plain of Lake Agassiz, sinking very slowly northeastward, reaches as far as the eye can see. On the south, flat land, covered by Lake Agassiz before the time of this beach, continues 1½ miles, ascending in that distance from 1,060 feet to about 1,080 feet, and moderately undulating till rises beyond to 1,100 and 1,125 feet.

One and a half miles north of this beach the Wild Rice River is crossed by a bridge near the center of Sec. 25, T. 132, R. 52. The stream in its ordinary stage is 1 to 2 rods wide, with a depth of about 3 feet, and is filled with grass and rushes. Its bottom land, a sixth to a third of a mile wide, is about 10 feet higher and is annually overflowed by the high water in spring. Its bluffs rise about 40 feet above the river at low water, the elevation of their top and of the adjoining plain being, approximately, 1,050 feet. These bluffs and the surface from the Herman beach north to Elk Creek are till, but the country about Wyndmere and south to Elk Creek is stratified fine clayey sand. Both formations have a very fertile soil, unsurpassed for wheat and all crops proper to this latitude. Elk Creek is a stream similar to the Wild Rice River, but smaller, and the width and depth of its valley are about two-thirds as great.

Northern Pacific, Fergus Falls and Black Hills Railroad: track at Wyndmere, 1,060 feet; at the Herman beach 1½ miles west of Wyndmere, track 1,064 and crest of the beach 1,065 feet, rising 8 feet above the adjacent land 20 rods away both east and west; surface along the railroad thence westward 8 miles, 1,060 to 1,063 feet, with Star Lake, a third of a mile in diameter on this level area, only 2 or 3 feet below the surrounding land, close north of the railroad, in Sec. 5, T. 132, R. 52; a higher beach of Lake Agassiz, crossed 3 miles east of Milnor, and therefore called the Milnor beach, crest and track, 1,083 feet, 4 or 5 feet above the adjoining land 10 rods away both east and west; another beach ridge formed during the same stage of Lake Agassiz, a third of a mile farther west, crest and grade, 1,084 feet; land close east, 1,079, and west, 1,076 feet; track at Milnor, 1,095 feet.

The Herman beach west and north of Wyndmere has an irregular surface, with frequent hummocks of sand heaped 5 to 10 feet above adjacent hollows. Most of these dunes are now grassed. From near Wyndmere this beach, with frequent small dunes, extends north through the west edge of T. 133, R. 51, and thence westerly to another tract of prominent dunes 50 to 100 feet above adjacent surface, with their tops at 1,100 to 1,150 feet, which extends about 10 miles in a west-northwest course from the southwest part of T. 134, R. 52, to the east part of T. 134, R. 54, terminating about 2 miles east of the Sheyenne River. Like the similar high dunes south of the Wild Rice River, these are mainly covered by herbage, bushes, and small trees; but many portions are

now being drifted by the winds, so that they are wholly destitute of vegetation. These dunes mark the course of the Herman beach, here greatly increased in volume by delta deposits from the Sheyenne River.

Morainic knolls and hills, rising 20 to 50 feet, with plentiful bowlders, lie close west of Milnor, extending in a belt from southeast to northwest. They are probably a continuation of the Altamont and Gary moraines of the Coteau des Prairies. Near Lisbon, about 15 miles northwest from Milnor, some of these morainic hills are quite conspicuous, rising 100 feet or more above the surrounding country.

Evidence of a stage of Lake Agassiz 20 or 30 feet higher than that of the Herman beach is found, as already noticed, in many places along the southern part of its boundary in Dakota. The portion of this glacial lake formed earliest by the recession of the ice seems to have reached from Lake Traverse to the Sheyenne River, and its level appears to have been then nearly that of the general surface and the top of the bluffs bordering Lake Traverse. Distinct traces of this stage of the ancient lake have not been recognized in Minnesota, nor along the greater part of its boundary in Dakota, from the Sheyenne River northward.

FROM MILNOR NORTH TO SHELDON.

The highest level of Lake Agassiz, near Milnor, is marked by the Milnor beach, already mentioned, where it is crossed by the railroad. This beach is fine clayey sand, in somewhat irregular and interrupted low ridges and terraces, abutting at the west on undulating till, which gradually rises 10 or 20 feet higher, while on the east a descent of 10 or 15 feet, within about 20 rods, is succeeded by a flat area, which thence sinks very slowly northeastward. The elevation of the Milnor beach at the railroad is 1,084 feet, and at Mr. G. V. Dawson's house, at the middle of the east side of Sec. 22, T. 133, R. 54, 1,092 feet. Its course between these points is north-northwest, and this is continued to the mouth of a former channel of the Sheyenne River, near the center of Sec. 4 in this township, 3 miles east from the most southern bend of the river.

During all the stages of Lake Agassiz the Sheyenne River brought into it much sediment, carrying the clay farther than the sand and gravel, which were laid down near the river's mouth. Extensive areas of these originally flat beds have been changed by wind action to irregular groups and belts of sand hills or dunes, which vary from a few feet to more than a hundred feet in height above the surrounding level. Besides the large tract of these dunes before described east of the Sheyenne River, others of even greater extent and equally conspicuous border the river and reach 2 or 3 miles from it in the northeast part of T. 135, R. 54, and along its next 15 miles.

Watercourses formerly occupied by this stream are found west of the Milnor beach. One of them is marked by a sandy flat, which reaches

from the present course of the Sheyenne River, in Sec. 1, T. 133, R. 55, southeastward through T. 133, R. 54, to the vicinity of Milnor. Another runs from near the middle of the SW. ¼ of Sec. 32, T. 134, R. 54, about 1¼ miles east-southeast to the middle of Sec. 4, T. 133, R. 54. This is a channel, 30 to 50 rods wide, about 40 feet below a ridge of coarse gravel, which extends along its northeast side, dividing it from the lower area that was covered by Lake Agassiz and from the present valley of the river. The crest of the ridge is nearly flat, upon a width of 10 to 30 rods, and is 75 to 100 feet above the river, being highest westward. It contains pebbles and cobbles of all sizes up to 6 inches in diameter, about half being limestone and nearly all the others granitic. This ridge or plateau of gravel is a remnant of an old delta plain of the Sheyenne River, apparently deposited before the formation of the Milnor beach, above which it rises some 40 or 50 feet, which suggests that the deserted channel of that depth on its south side was probably eroded during the Milnor stage of Lake Agassiz. Similar gravel occurs on the side and verge of the bluff, 100 feet high, northwest of the Sheyenne River, in the SW. ¼ of Sec. 29, T. 134, R. 54, but a rolling surface of till extends thence northwest.

Sheyenne River in Sec. 32, T. 134, R. 54, 1,037 feet above the sea, and on the west line of the NW. ¼ of Sec. 29, T. 135, R. 54, 1,019 feet. Its bed through these townships is mostly 4 to 6 rods wide, with water 1 to 2 or 3 feet deep, and is strewn in many places with cobbles and bowlders up to 2 or 3 feet and rarely 6 or 8 feet in diameter. Its bottomland near the south bend, about a third of a mile wide, is 15 or 20 feet above the ordinary low stage of water, and during a term of fourteen years preceding this survey in 1885 it had not been overflowed; but driftwood, found by the first immigrants, proves that the river sometimes reaches this height. Bluffs of till here, in the southwest corner of T. 134, R. 54, rise 100 to 125 feet above the stream.

Bluffs of till close west of the Sheyenne River, in Sec. 20, T. 134, R. 54, 1,100 to 1,110 feet; moderately rolling till a quarter of a mile farther west, 1,115 to 1,125 feet; same in Secs. 17 and 18, 1,090 to 1,130 feet; and on the east side of the river, in Secs. 21, 16, and 17, 1,085 to 1,075 feet, descending northeastward. Prominent swell of till west of the Sheyenne River in the SE. ¼ of Sec. 30, T. 135, R. 54, having four aboriginal mounds on its crest, 1,113 feet; top of these mounds, 1,117 feet, very nearly. Highest portions of the area of undulating till seen westward from this Sec. 30, 3 or 4 miles distant, 1,125 to 1,150 feet.

Surface at Charles G. Froemke's house, in the NW. ¼ of Sec. 29, T. 135, R. 54, 1,073 feet; bottom land of the Sheyenne River close west, 1,037 to 1,027 feet; ordinary low water of the river, 1,019 feet.

Portion of area of Lake Agassiz, a strip a fourth to a third of a mile wide, west of the Sheyenne River, in Secs. 32 and 5, a half mile to 2 miles south of Mr. Froemke's, 1,065 to 1,075 feet. Herman beach one-fourth to two-thirds of a mile east of the Sheyenne River here and ex-

tending southeasterly toward the western limit of dunes in the east part of T. 134, R. 54, 1,073 to 1,079 feet. Crest of this beach, a low ridge of sand and fine gravel, at J. Altmann's house, near the middle of Sec. 20, T. 135, R. 54, 1,073 feet. Within 10 or 15 rods east there is a descent of about 10 feet. This beach ridge runs north and northeasterly to near the northeast corner of this Sec. 20, and thence it passes eastward about 3 miles, having an elevation of 1,075 to 1,065 feet to where it is intersected by the Sheyenne River, near the northeast corner of Sec. 14. North of the river it continues about a half mile in Sec. 12, its elevation being 1,065 to 1,070 feet, to the west end of a tract of dunes 25 to 100 feet above their vicinity, with summits at 1,100 to 1,150 feet, which extends thence about 15 miles eastward. This Herman beach was sufficient to turn the course of the Sheyenne River along its west and north side for a distance of 8 miles, from Sec. 9, T. 134, R. 54, north and east to Sec. 14, T. 135, R. 54, though it is only a ridge of sand and gravel 5 to 10 feet higher than the smoothed area of till, occasionally covered by 1 to 3 feet of sand, which lies west of it and in which the river has now cut its channel 50 to 60 feet deep.

Rolling surface of till in the south edge of Sec. 9, T. 135, R. 54, 25 to 40 rods north of the Sheyenne River, 1,080 to 1,090 feet. Most of this Sec. 9 is nearly level till at 1,080 to 1,085 feet, with occasional large hollows 20 feet lower. It seems to have been smoothed by Lake Agassiz at the time of the Milnor beach. Westward is slightly undulating till, having an elevation of 1,085 to 1,125 feet for 2 or 3 miles, as far as the surface lies within view.

Herman beach in the NW. ¼ of the NW. ¼ of Sec. 10, T. 135, R. 54, 1,075 to 1,080 feet. This is a deposit of gravel and sand extending along the verge of the plateau of till just described in Sec. 9. Fifteen or 20 rods to the east the elevation is 1,065 feet, and it sinks slowly thence eastward to about 1,050 feet at the west base of the dunes in Secs. 12 and 1 of this township.

Lakelet back of this beach, situated in the east edge of the SE. ¼ of Sec. 4, T. 135, R. 54, about 50 rods long from south to north, 1,060 feet, being 25 feet below the average of the adjacent undulating till. Shallow lakelet, 40 rods across, close east of the beach, a quarter of a mile east from the northwest corner of Sec. 3, also 1,060 feet; adjoining land, 1,065 to 1,070 feet, excepting on the west, where the Herman beach has an elevation of 1,080 feet, with undulating till beyond it a few feet higher.

Herman beach at the middle of the west side of Sec. 34, T. 136, R. 54 (Sheldon), 1,082 feet; surface 25 rods east, 1,070 feet, thence descending slowly eastward. Here and for 1½ miles south, through Sec. 3, this beach is a flattened ridge of sand and fine gravel, 25 or 30 rods wide, with a depression 3 to 6 feet deep along its west side. In the NW. ¼ of Sec. 28, its elevation is 1,080 feet.

Fargo and Southwestern Railroad track at Sheldon, 1,078 feet. Wells in Sheldon village are 10 to 15 feet deep, in sandy clay free from

gravel or bowlders 6 to 10 feet, with sand below. These deposits belong to the Herman beach, which is here spread upon a width of about a half mile.

FROM SHELDON NORTH TO THE NORTHERN PACIFIC RAILROAD.

This beach, terracelike, at Hugh McIntosh's house, in the south edge of the NW. ¼ of Sec. 8, T. 136, R. 54 (Sheldon), has its crest 1,083 to 1,084 feet above the sea. His well, near the top of the beach, 22 feet deep, is soil and sandy clay to a depth of 7 feet, then sand 15 feet to water. Till rises to the surface 20 rods farther west. About 30 rods east, on land 10 feet lower, a well 10 feet deep is all caving sand below the black soil, which is 1 or 2 feet deep next to the surface.

From the east base of the beach near Mr. McIntosh's there is a very slight descent eastward to 1,065 feet, approximately, about Island Lake, which lies some 10 feet lower. This lake, nearly round, about a third of a mile in diameter, is crossed by the line between Secs. 9 and 10. Its island, which is said to have an area of 12 acres, lying in Sec. 9, is wooded; but the shores around the lake are destitute of timber, being in part marshy, with grass and rushes, and in part hard sand. The maximum depth of water is only 6 feet, but it has not been dried up during the six years from the first immigration here to the time of this survey.

Maple River in Sec. 32, T. 137, R. 54, about 2 miles northeast from its most southern bend, 1,017 feet. It is 20 to 40 feet wide and 1 to 3 feet deep, with cobbles and bowlders in many portions of its channel.

Herman beach, a sand and gravel deposit extending a quarter of a mile from south to north on the verge of the bluff of till west of Maple River in the northwest part of this Sec. 32, 1,072 to 1,077 feet. In the north edge of the NW. ¼ of this section, the northeast corner of Sec. 31, and the east edge of Sec. 30, it is a plateaulike tract a fourth of a mile wide, with a subsoil of sand and fine gravel, 1,086 feet, from which both east and west a gentle slope falls 5 feet within 20 or 30 rods. In the NW. ¼ of Sec. 20 and the west half of Sec. 17, it is a gracefully rounded ridge, 1,085 to 1,087 feet, with descent of about 5 feet on its west side and 10 to 15 feet within as many rods on the east. The surface east of the Maple River in this T. 137, R. 54, has an elevation of 1,075 to 1,065 feet, declining toward the north and east.

In the east half of T. 137, R. 55, a surface of till, moderately undulating near the beach of Lake Agassiz, but prominently rolling at a distance of 3 miles to the west, rises to 1,150 and 1,175 feet in the vicinity of the Maple River above its south bend.

The Herman beach, a broad flattened ridge of sand and gravel, passes in a north-northeast course through the center of Sec. 8, T. 137, R. 54, its elevation being 1,083 feet. A smoothed surface of till, 1,082 to 1,087 feet, with occasional sloughs in depressions 15 to 20 feet deep, occupies

the west half of this Sec. 8; and close east of the beach a flat of till on the east line of the section, at 1,065 to 1,070 feet, was the bed of the lake.

Continuing northeastward, the beach is offset a mile to the east in Secs. 4 and 3, T. 137, R. 54, so that the greater part of Sec. 4 was a bay of Lake Agassiz during its Herman stage, with bottom at 1,080 to 1,065 feet, inclosed on the west, north, and east by beach deposits. The highest portion of the hook or spit east of this bay is in the SW. ¼ of Sec. 3, 1,093 to 1,096 feet. It is composed of sand and fine gravel, with pebbles, mostly less than an inch but occasionally 2 inches in diameter, forming a smoothly rounded swell 30 to 40 rods wide. This cape, projecting south and west a mile into the lake, was accumulated by the southward drift of the beach material along the shore, caused by northern winds, as is also observable at various other places on both the east and west shores of this extinct lake and on both sides of Lake Michigan at the present time.

Herman beach in the west edge of Sec. 26, T. 138, R. 54, 1,094 feet. On the east side of the beach here, near the center of this section, is a slough filled with rushes and containing water all the year; its elevation is about 1,065 feet, that of the land on its east side in the east part of this section being about 1,075 feet. In the NE. ¼ of the NE. ¼ of Sec. 34, the beach is intersected by a sluggish creek, apparently formed by springs within a half mile northwest, its ravine being fully 40 feet below the general level of the beach and the land westward. Again, in the NW. ¼ of the SW. ¼ of Sec. 26, the beach is cut by a dry channel, the outlet in rainy weather from a small slough.

Through the west half of Sec. 23, T. 138, R. 54, the beach is a low, smoothly rounded ridge of sand and fine gravel, about half of which is limestone and the rest granite or other Archean rocks. As in the 3 miles next southward, it is largely composed of fine gravel, and pebbles abound, often covering half the surface of the knolls made by gophers. Most of the pebbles are less than an inch in diameter, but some measure 2 and a few 3 inches. The elevation of this beach ridge is 1,092 to 1,100 feet; on the north line of this section its height is 1,099 feet. A broad depression 3 to 5 feet below the beach borders its west side. Toward the east there is a descent of about 10 feet in 25 or 30 rods, and thence a gradual slope sinks to 1,060 or 1,050 feet within 1 to 1½ miles.

Undulating till in Secs. 22 and 15, T. 138, R. 54, 1,095 to 1,110 feet; crests of prominently rolling till in the west edge of Sec. 11 and the south part of Sec. 10, 1,115 to 1,125 feet; thence northwestward lower undulating till has an elevation of only 1,090 to 1,100 feet for nearly two miles and rises quite slowly beyond.

This somewhat irregular contour has caused considerable diversity in the development of the beach, so that its deposits are massed in unusual amount in some places, while elsewhere they are deficient or wholly wanting. In the SW. ¼ of the SW. ¼ of Sec. 14, T. 138, R. 54,

a swell of gravel, with pebbles of all sizes up to 2 inches or rarely 3 inches in diameter, rises to 1,105 feet, extending about 40 rods from south to north; and similar gravel, at 1,095 to 1,105 feet, occurs in the west part of the NW. ¼ of Sec. 23, west of the distinct beach ridge. The northwest part of Sec. 14 is a nearly flat tract, having a subsoil of sand and fine gravel, with an elevation of 1,090 to 1,095 feet. Beach ridge extending south from the east side of a prominent swell of till in the SW. ¼ of Sec. 11, 1,086 to 1,089 feet, having a continuous depression of about 5 feet on its west side and bordered eastward by land 6 to 10 feet below its crest. In the northwest part of this Sec. 11 and the southeast part of Sec. 3 the shore of Lake Agassiz is marked by slight erosion in the rolling and undulating surface of till rather than by the usual beach deposits of gravel and sand.

Beyond this, a conspicuous beach ridge 25 to 40 rods wide, elevated 10 feet above the undulating till on its west side and bordered by a still lower surface on the east, extends from the middle of the SW. ¼ of the SE. ¼ of Sec. 3, T. 138, R. 54, northwestward to near the middle of the north line of the NW. ¼ of this section, where it is interrupted by a drainage gap about 20 feet below its crest. Thence this massive beach ridge continues in a north-northeast course through Sec. 34, T. 139, R. 54, to near the middle of its north line. Its material is sand and gravel, with pebbles up to 1½ inches in diameter. In Sec. 3 its elevation is 1,095 to 1,090 feet, and in Sec. 34, 1,089 to 1,094 feet. It passes onward as a very distinct and typical beach ridge, with the same north-northeast course, through Secs. 27 and 22, T. 139, R. 54, having an elevation of 1,087 to 1,095 feet in Sec. 27 and 1,089 to 1,096 feet in Sec. 22. Its eastern slope in these sections descends 15 to 20 feet.

About a half mile west from this great beach ridge the east edge of Sec. 4 has irregular deposits of beach gravel and sand in swells and bars 5 feet above the general level, and in the east edge of Sec. 33, T. 139, R. 54, a well defined parallel beach begins, having a width of 20 to 25 rods and elevation of 1,092 to 1,094 feet, with a depression 2 to 4 feet lower on the west and descent of about 5 feet on the east. This western Herman beach extends as a continuous ridge 2 miles to the north-northeast, excepting a gap where it is intersected by a small stream in the NW. ¼ of Sec. 27. Its material is sand and gravel, with pebbles up to 2 inches in diameter, about half of which are limestone. Both this and the east beach have a black soil a foot or more in depth, and are scarcely inferior to the adjoining areas of till in productiveness. Farther west a slightly undulating or nearly flat surface of till extends from a half mile to 1½ miles before it rises above 1,095 feet; and the highest of its swells, seen 3 to 6 miles away to the west and northwest, do not exceed 1,150 or 1,175 feet. Western Herman beach on the north line of the NW. ¼ of Sec. 27, 1,095 feet; about 6 rods to the south, 1,097 feet, and northeastward, in Sec. 22, 1,092 to 1,095 feet, to its junction with the eastern or main beach in the east part of this section.

A lower Herman beach, formed after the lake level here had fallen slightly, appears in the northwest edge of Sec. 26, T. 139, R. 54, having its crest at 1,072 to 1,075 feet; passing north-northeast.
west half of Sec. 23, its elevation is 1,075 to 1,080 feet; through Sec 14, 1,080 to 1,087 feet, being highest near the center of this section; and in the east part of Secs. 11 and 2 and northward to the SW. ¼ of Sec. 36, T. 140, R. 54, 1,083 to 1,080 and 1,075 feet. Its maximum development is in Sec. 14, where it is a massive, smoothly rounded ridge of sand and fine gravel, 30 rods wide, with a descent of 15 feet on each side. In Secs. 26 and 23 it is bordered on the west by a continuous depression 4 to 8 feet below it; and, through Secs. 14, 11, and 2 and in the SW. ¼ of Sec. 36, a slough 3½ miles long, mown for its luxuriant marsh hay, having an elevation of 1,067 to 1,072 feet, lies between this and the main beach, a half mile farther west.

Floor of S. P. Gardner's house, in the northwest corner of Sec. 27, T. 139, R. 54, 1,096 feet.

Main Herman beach through the west edge of Sec. 14, T. 139, R. 54, 1,096 to 1,093 feet, declining northward; in the west part of Sec. 11, 1,093 to 1,095 feet; in Sec. 2, 1,092 to 1,095 feet, changing from a north to a north-northeast course; in the southeast edge of Sec. 35 and the northwest edge of Sec. 36, T. 140, R. 54, 1,092 to 1,096 feet; and in the west part of Sec. 25, where it is cut by the Northern Pacific Railroad, 1,093 to 1,099 feet. At the railroad cut its crest is 1,097 to 1,099 feet and the track is 1,091 feet. Along this distance of 5 miles it is a typical beach ridge of sand and gravel, with pebbles up to 2 inches and occasionally 3 to 6 inches in diameter, about 30 rods wide, rising nearly 25 feet above the slough on the east, and bordered on the west by a continuous depression, mostly about an eighth of a mile wide, 3 to 7 feet below its crest. Slightly undulating till rises beyond to 1,125 and 1,140 feet within 1 or 1½ miles west, which is as far as the surface lies within view.

Northern Pacific Railroad, track at Wheatland, 991 feet; on bridge over creek in the east edge of Sec. 25, T. 140, R. 54, 4 miles west of Wheatland and three-fifths of a mile east of the Herman beach, 1,074 feet; bed of the creek, 1,055 feet; track at summit, 4½ miles west from the Herman beach, same as the natural surface, 1,206 feet; and at Buffalo, a half mile farther west, 1,200 feet.

FROM THE NORTHERN PACIFIC RAILROAD NORTH TO GALESBURG.

Herman beach, a broad, smoothly rounded, continuous ridge of the same material and contour as southward, for the next 4 miles north from the Northern Pacific Railroad, bearing north-northeast, 1,097 to 1,100 feet, very constant in elevation. The descent of its east slope is 15 or 20 feet in about 20 rods, and of its west slope, about 5 feet. Thence westward the surface is undulating till, in swells 10 to 15 feet above the

depressions, rising gradually to 1,150 and 1,200 feet above the sea at a distance of 3 to 5 miles, the farthest seen in that direction. In a broad view this area seems an almost flat plain.

Where this beach is cut by the Saint Paul, Minneapolis and Manitoba Railway from Ripon to Hope, near the middle of the line between Secs. 32 and 33, T. 141, R. 53, its crest was 1,096 to 1,099 feet above the sea. It has been excavated here for ballast to a distance of about 30 rods south from the railway. It is mostly gravel; the pebbles seldom exceed 2 inches in diameter; about half is limestone and the remainder granitic. The thickness of this beach deposit is only 8 to 10 feet; its east slope falls 12 or 15 feet, and its west slope, 5 to 7 feet.

On the floor of this excavation, about 10 rods south from the railway, in the upper foot of the till or bowlder clay, under the gravel, numerous bones of a mammoth were found in the year 1884. These included a tusk 11 feet long and 9 inches in diameter (tapering to 6 inches at the smaller end, where it was broken off), three teeth, two vertebræ, and several other bones. They were embedded in the top of the till, and the overlying beach formation has yielded no bones, shells, or other fossils.

Southward from this locality the Herman beach is double for a distance of about 4 miles. The secondary beach ridge east of that already described is similar in size and material. Its south end is in the west part of Sec. 19, T. 140, R. 53, a half mile east from the main beach, and it passes thence north-northeastward through Secs. 18, 7, and the east edge of Sec. 6, having an elevation of 1,081 to 1,084 feet. It becomes merged with the main beach in the SE. ¼ of Sec. 32, T. 141, R. 53. Between these beach ridges is a depression, approximately 1,075 feet, partly occupied by a grassy slough, which is all used as mowing lane, having no area of water or bog.

Herman beach, in the SW. ¼ of Sec. 28, T. 141, R. 53, 1,094 to 1,096 feet, not so distinct as usual, being intersected by Swan Creek and having no well marked depression along its west side. Farther north in this section it is a ridge of the ordinary type, with its crest at 1,096 to 1,098 feet. In Sec. 21 it is narrowed to 8 or 10 rods in width, but continues as a very distinct ridge with a slight ascent northward, from 1,097 to 1,101 feet. Its east slope falls 15 to 20 feet in about 20 rods and there is a depression of 3 to 6 feet on the west. Thence a surface of undulating till, seeming nearly flat in a general view, rises gradually westward to about 1,150 feet at a distance of 2 or 3 miles.

This beach ridge passes onward through Sec. 16 and the south part of Sec. 9, T. 141, R. 53, with an elevation of 1,095 to 1,100 feet; but, having been followed thus continuously in a north-northeast course for more than 15 miles, it ceases in the east part of this Sec. 9. Its north end abuts at 1,100 to 1,105 feet upon a terrace slope of till, which rises about 10 feet higher. This forms the east boundary of a slightly undulating expanse of till, which thence gradually rises to 1,150 and 1,200 feet in 2 to 5 miles west and northwest. From Sec. 9 northward through

the east part of Sec. 4 and in the west edge of Sec. 34 and the west part of Secs. 27, 22, and 15, T. 142, R. 53, passing close east of Erie, the Herman shore of Lake Agassiz is marked by such a terrace or escarpment formed by wave erosion, and the usual deposit of beach gravel and sand is absent. The base of the escarpment is at 1,095 feet, approximately, and it rises with a moderate slope 25 to 40 feet.

About a half mile east of this escarpment, however, lies a broad low ridge of beach sand and fine gravel, having an elevation of 1,085 to 1,090 feet. Its course is from the west part of Sec. 10 north-northeast through Secs. 3 and 34 and nearly due north through the east edge of Secs. 27, 22, and 15. The descent eastward is more gentle than usual, falling only 6 to 10 feet in a quarter of a mile, beyond which is a flat area of till. On the west a depression 3 to 5 feet deep, partly occupied by a grassy slough, intervenes between this beach ridge and the wave-cut escarpment. On the north line of Sec. 15 the crest of the ridge is at 1,092 feet; the depression west, 1,088; the base of the escarpment, 1,092, and its top, about 1,115 feet.

Saint Paul, Minneapolis and Manitoba Railway from Ripon to Portland, track at tank and section-house close south of Rush River, 1,096 feet; at Erie, 2 miles farther north, 1,128 feet; summit, about 1 mile north of Erie, 1,133 feet; South Branch of the North Fork of Elm River, bridge, 1,083 feet; bed of creek, 1,064 feet; track at summit 1 mile north, 1,091 feet; at Galesburg, 1,081 feet; North Branch of the North Fork of Elm River, bridge, 1,078 feet; bed of creek, 1,065 feet; track at Clifford, 1,057 feet. At Erie and westward the surface is prominently rolling till, which rises within 3 miles to a height 100 feet above the shore of Lake Agassiz.

In Secs. 10 and 3, T. 142, R. 53, the Herman beach is again well exhibited in its usual character. On the north line of Sec. 10 it is a gently rounded ridge of sand and gravel, with pebbles up to 2 inches and rarely 3 or 4 inches in diameter, half being limestone; its width is about 20 rods; the elevation of its crest is 1,106 feet and the slopes fall 10 feet on the east and 3 feet on the west. For the next mile northward, through the west part of Sec. 3, this beach ridge has a width of 10 to 15 rods; its elevation is mostly 1,105 to 1,108 feet, with a depression 5 to 7 feet deep along its west side; but in a few places the ridge itself is depressed to 1,099 feet. Passing northward this beach in the west half of Sec. 34, T. 143, R. 53, is a very smooth, gracefully rounded, wavelike swell, 30 to 40 rods wide, 1,108 to 1,112 feet in elevation, rising 15 feet above its east base and having a depression of 3 to 5 feet on the west. A well in the NE. ¼ of the SW. ¼ of Sec. 34, on the top of this beach, went through 12 feet of sand and gravel, going into till below. In the SW. ¼ of Sec. 27, the beach continues with the same massive development and nearly north course, its elevation being 1,111 to 1,115 feet. In the NW. ¼ of this section it becomes a still broader deposit of gravel and sand, a fourth to a third of a mile wide, with no depression on its

west side. Here its course is turned northwestward, entering the SE. ¼ of Sec. 21 with an elevation of 1,109 feet; but it seems not to be distinctly traceable farther. About a half mile west of this beach a plateau of till, 1,125 to 1,128 feet above the sea, extends a third of a mile from southeast to northwest in the SE. ¼ of Sec. 28; but for a mile south and west of this plateau and for 3 miles northwest the surface of slightly undulating till averages only 1,105 to 1,120 feet.

The secondary Herman beach, already described in its course east of the Erie escarpment of till, continues northward with an elevation of 1,095 feet, approximately, through the east half of Secs. 10 and 3, T. 142, R. 53, and Secs. 34 and 27, T. 143, R. 53. In Secs. 22 and 16 this beach turns in a gradual curve to the northwest and west and its crest varies in height from 1,095 to 1,104 feet, being highest in or near the southeast corner of Sec. 16. There it is a ridge of gravel and sand about 30 rods wide, rising 10 to 15 feet above its northeastern base and descending 6 to 10 feet on the southwest to a nearly flat tract of moist mowing land fully a mile wide, with a height of 1,090 to 1,095 feet. Through Secs. 17, 8, and 5 it again curves to the northwest, north, and north-northeast, having an elevation of about 1,100 feet. In the north half of Secs. 5 and 4, T. 143, R. 53, a smooth plain with sand subsoil extends a mile eastward from the east base of this beach ridge, descending in this distance from 1,090 to 1,075 feet.

Continuation of this beach northward nearly through the middle of Sec. 32, T. 144, R. 53, 1,096 to 1,099 feet. It is a typical beach ridge of fine gravel and sand 8 to 10 feet above the land on its east side and having a descent of about 5 feet westward, beyond which the surface of undulating till rises in 1 or 1½ miles to 1,125 and in the next 2 miles to 1,175 or 1,200 feet. A half mile east from this beach and only 20 to 30 rods west of the railroad, there is a parallel beach ridge of similar size and material, 1,090 to 1,092 feet. The former of these beaches, where it crosses the south line of Sec. 20, a fourth to a half mile west of Galesburg, is spread in a broad, nearly flat deposit which rises westward from 1,096 to 1,101 feet. On the west it is bordered by a depression about 8 feet lower.

FROM GALESBURG NORTH TO LARIMORE.

In Sec. 20, T. 144, R. 53, the beach is about a third of a mile wide, its higher western margin being at 1,097 to 1,102 feet. From its crest a slope descends first somewhat steeply and then slowly to the amount of 20 or 25 feet in two-thirds of a mile eastward, having a subsoil of sand and very fine gravel to a depth of 5 to 10 feet, underlaid by till, as is shown by wells at Galesburg. Crest of this beach through the west half of Sec. 17, 1,102 to 1,107 feet; in Sec. 6, T. 144, R. 53, where it is intersected by the North Branch of the North Fork of Elm River, and in Secs. 32 and 29, T. 145, R. 53, 1,115 to 1,125 feet, being 10 to 15

feet higher than on the south and north; in Secs. 20 and 17, about 1,110 feet; in the southwest part of Sec. 8, 1,117 feet; westward through Sec. 7 of this township and through the northeast part of Sec. 12, T. 145, R. 54, 1,112 to 1,117 feet. In the west part of Sec. 7 a slough about an eighth of a mile wide, having an elevation of 1,100 feet, approximately, borders the southwest side of this beach ridge. On the line between Traill and Steele Counties, where the top of the ridge is at 1,114 feet, it is a typical beach deposit about 25 rods wide, composed of sand and gravel, with pebbles up to 2 or 3 inches in diameter. Its course is due west, and the descent from crest to base on the south is 6 or 8 feet and northward 12 or 15 feet, beyond which a very gentle slope sinks toward the northeast. A well on this beach, in the east edge of the NW. ¼ of Sec. 12, T. 145, R. 54, went through sand and fine gravel 13 feet, finding till below. Within a few hundred feet farther west the beach is interrupted for a distance of about 1 mile by an area of till some 15 feet lower, with no beach deposits. It reappears, however, as a typical beach ridge of gravel and sand for a distance of three-fourths of a mile in the NW. ¼ of Sec. 11 and the NE. ¼ of Sec. 10, having an elevation of 1,114 to 1,112 feet, with a slough on its south side 6 to 8 feet lower.

Returning to the vicinity of Galesburg, a slightly higher beach, approximately parallel with the foregoing, remains to be traced. It becomes recognizable in the west edge of Sec. 20, T. 144, R. 53, where the border of the area of rolling till that extends thence westward bears occasional deposits of gravel at 1,115 to 1,120 feet. In the east part of Sec. 18 it is a well developed beach ridge of sand and fine gravel 30 to 50 rods wide, with a depression on the west 4 to 6 feet below its top, which has an elevation of 1,120 to 1,123 feet. The next half mile or more westward in Sec. 18 is very smooth till, 1,120 to 1,125 feet; but within one mile farther west prominent swells of till rise to 1,160 and 1,175 feet. Northward in Sec. 7 this beach, continuing at 1,120 to 1,123 feet, is quite broad, without a distinctly ridged form, and is indented from the east by a large slough, whose elevation is approximately 1,100 feet, including several acres of water free from grass and rushes. Crest of beach in the SW. ¼ of Sec. 6, 1,122 to 1,126 feet. North Branch of the North Fork of Elm River 1,105 feet, dry in summer, in a valley 15 to 40 rods wide. Beach through Secs. 31 and 30, T. 145, R. 53, 1,125 to 1,129 feet; and in the west half of Sec. 19, 1,127 to 1,124 feet, sinking slightly from south to north. The farther course of this shore is not marked by continuous beach deposits; but, following the contour line of 1,125 feet, it must turn west in the SW. ¼ of Sec. 18, T. 145, R. 53, and extend through Secs. 13 to 16, T. 145, R. 54, to the South Branch of Goose River.

Highest ground crossed by road on the line between Traill and Steele Counties at the west side of Sec. 18, T. 145, R. 53, 1,125 feet.

Natural surface at the southwest corner of Sec. 3, T. 145, R. 54, a dozen rods west of the South Branch of Goose River, 1,104 feet. This

stream, about 1,070 feet, is 8 to 20 feet wide and mostly 1 to 2 feet deep. Its bottom land, 5 to 10 feet above this stage of low water, varies from 20 to 100 rods in width and is inclosed by bluffs rising 30 to 50 feet, increasing in height southwestward. The valley has no timber, the largest wood growth being willows 5 to 8 feet high and 2½ inches or less in diameter. With the aid of these, however, beavers construct dams and were living on this stream when this survey was made in 1885, one of their dams then occupied being found by my assistant in the west edge of Sec. 10, T. 145, R. 54.

Floor of Henry Bentley's barn in the southwest corner of the SE. ¼ of Sec. 6, T. 145, R. 54, on the Herman shore of Lake Agassiz, 1,123 feet. This is a moderate slope, ascending 10 or 15 feet, eroded in till, which from its top stretches westward about 2 miles in a nearly level expanse. From the south side of Sec. 6, such a low escarpment, with its top at 1,120 to 1,123 feet, extends due north, or a few degrees west of north, about 5 miles.

E. W. Palmer's house, in the northwest corner of the SW. ¼ of Sec. 2, T. 145, R. 55, 1,145 feet. Well here, 27 feet deep: soil and hard cemented gravel and sand, 2 feet; sand with occasional layers of fine gravel, 22 feet; and darker clayey quicksand, 3 feet, with water.

This is on the west part, nearly at the crest, of an unusually high beach of this glacial lake, similar in elevation with the Milnor beach, farther south. Including its slopes, it has a width of 60 rods, the nearly flat crest being 40 rods across and in elevation 1,142 to 1,147 feet. The depression on the west falls about 5 feet. In the north part of Sec. 2 the beach deposits have an irregular contour, not lying as usual in a continuous ridge; their highest portions vary from 1,145 to 1,152 feet. Southward from Sec. 2 this shore line is not marked by a continuous beach formation, but is interrupted by wide depressions where the surface is till. Beach gravel and sand appear, however, in some amount at Mr. Thomas Ward's, in the southwest corner of Sec. 11, T. 145, R. 55; also, in the southwest part of Sec. 23, nearly 2 miles farther south. Within 1 to 3 miles west from these sections an area of undulating and rolling till rises to 1,200 and 1,250 feet.

Near the middle of the north half of Sec. 23, T. 146, R. 55, the elevation of this beach is 1,142 to 1,144 feet. It is a ridge of gravel and sand, extending a quarter of a mile from southeast to northwest, with crest 15 feet above the surface on each side. Toward the east it descends in a long slope, but more steeply westward. In Sec. 14 this shore line curves westerly, the crests of its somewhat irregular beach deposits being about 1,135 feet, with a descent of 10 to 15 feet in 25 rods east. Through Sec. 11 they range from 1,135 to 1,147 feet, being highest in the SE. ¼, where the descent eastward is 20 feet or more. These beach deposits are sand and gravel, with pebbles up to 1½ or 2 inches in diameter, massed in flattened hillocks or swells, mostly ridged lengthwise with the shore and occasionally inclosing hollows without outlet. The forma-

tion has a width of a quarter of a mile or more in its northward course through the west part of the east half of Sec. 11. An undulating surface of till rises slowly to the west, while on the east a very smooth expanse of till sinks slowly toward the Red River.

Herman beach ridge, 30 rods wide, in or near the east edge of the SE. ¼ of Sec. 2, T. 146, R. 55, 1,125 feet. Irregular accumulations of the higher beach a quarter of a mile farther west, approximately, 1,140 feet. These upper deposits and those described in the last two paragraphs seem to have been formed while the level of this margin of Lake Agassiz was held above its Herman stage by the barrier of the retreating ice sheet, still remaining unmelted within a few miles east, and by that of the high area on the south in Ts. 144 and 145, R. 54.

Crest of the Herman beach, a definite ridge 25 to 30 or 40 rods wide, through the east half of Sec. 2, T. 146, R. 55, 1,122 to 1,135 feet, 10 to 15 feet above the land east and with a depression of 6 to 8 feet on the west. In the south part of Sec. 35, T. 147, R. 55, the beach ridge is merged in a flat, eastwardly sloping area of sand and fine gravel at 1,135 to 1,120 feet, underlaid by till at the depth of a few feet. The beach ridge reappears in the north part of this Sec. 35 at 1,125 to 1,130 feet.

North Fork of the Middle Branch of Goose River, where it intersects the Herman beach in the southeast part of Sec. 26, T. 147, R. 55, approximately, 1,085 feet. Its bottomland is 30 to 80 rods wide, bordered by bluffs rising 30 to 40 feet.

Through Secs. 26 and 23, T. 147, R. 55, the Herman shore is marked by swells and flattened ridges of sand and fine gravel at 1,130 to 1,143 feet, occupying a width of an eighth to a third of a mile, with a depression of several feet along their west side. Four sloughs, elevation about 1,120 feet, lie within the east part of these beach deposits, or on their east border, in the SE. ¼ of Sec. 23. In the south part of Sec. 14, this massive but irregular beach has an elevation of 1,132 feet on the east side of a large slough.

In the middle of Sec. 14, T. 147, R. 55, the beach assumes a definitely ridged form and extends thus northward along the east side of Golden Lake, which owes its existence to this barrier. Crest of beach, through the center and north part of Sec. 14, 1,132 to 1,137 feet; in Sec. 11, east of Golden Lake, 1,132 to 1,141 feet; and at Golden Lake post office, in the east edge of the SW. ¼ of Sec. 2, 1,138 feet. An eighth of a mile north from the south end of this lake the action of its waves has eroded the greater part of the beach ridge. The material of the beach exposed by an excavation near the post office is coarse gravel, with very abundant pebbles up to 3 and occasionally 4 to 6 inches in diameter.

Golden Lake, water July 28, 1885, 1,122 feet above the sea; highest level reached by this lake in recent years, 1,128 feet. It is a beautiful sheet of water, 1¼ miles long and a quarter to a third of a mile wide. Its west shore is moderately undulating till, with the highest swells 20 to 30

feet above the lake. In a few places its grassed bluffs rise steeply from the water's edge 10 to 20 feet. Farther west the rolling surface of till, seen for a distance of 3 or 4 miles, rises to 1,225 or 1,250 feet. This lake has no trees on its margin, excepting two small cottonwoods, each about 25 feet high, on its northwest shore; bushes grow in several places, mostly on the east; but the greater part of the lake border, like all the surrounding country, is prairie.

Beach ridge through the north part of Sec. 2, T. 147, R. 55, 1,138 to 1,132 feet. In the south half of Sec. 35, T. 148, R. 55, it has been mostly eroded by a lake which borders this beach on the east from the north part of Sec. 2 to the north part of Sec. 35, having a length of 1 mile and a width of an eighth to a fourth of a mile. The elevation of this lake is 1,104 feet. It has no trees nor bushes, excepting a few willows 4 to 6 feet high near the middle of its west side, and is wholly surrounded by hard grassy shores. Crest of beach west of the north part of this lake, 1,140 to 1,142 feet, and through the south half of section 26, 1,137 to 1,142 feet, similarly bordered on the east by two lakelets, which have approximately the same height as the preceding, 1,104 feet. The land east of these three lakes is flat, 1,113 to 1,117 feet near them, with a very gentle slope descending thence eastward.

More diffuse and irregular beach deposits in north to south swells and short massive ridges of gravel and sand, inclosing occasional hollows with no outlets, some of which hold small ponds and sloughs, extend from the north edge of Sec. 26 northward through the west half of Sec. 23, T. 148, R. 55, with an elevation of about 1,135 feet. The depression on the west is some 5 feet lower and on the east there is a descent of 10 feet from the crest to the base of the beach. Fingal's Creek in the northwest corner of section 23, where it intersects the beach, about 1,110 feet. Undulating and rolling till within 3 or 4 miles westward rises to 1,250 feet.

Herman beach through the west part of Sec. 14, T. 148, R. 55, 1,142 to 1,147 feet, being mainly a somewhat typical ridge, with short swells of beach gravel and sand on its east side 10 to 15 feet lower, inclosing hollows, but few or no sloughs. Two lakes at 1,110 feet, approximately, lie close east of this beach near the center and in the NW. ¼ of this section. They are bordered on the east by land 10 feet higher, from which a very gentle descent sinks toward the Red River.

Continuation of this beach ridge northward through the east edge of Sec. 10, T. 148, R. 55, 1,142 to 1,146 feet, 3 to 5 feet above the depression on its west side. On the east, three lakelets at 1,120 feet, approximately, lie in the west edge of the NW. ¼ of Sec. 11, each being about 20 rods long from south to north and 15 rods wide. Crest of beach ridge, 30 to 40 rods wide, extending nearly due north through the east edge of Sec. 3, 1,144 to 1,150 feet; east base about 1,125 feet; depression on the west, 5 to 10 feet, nearly level upon a width of 40 rods; beyond is an ascent of undulating and rolling till to 1,250 feet within 2

or 3 miles. In the SW. ¼ of the SW. ¼ of Sec. 36, T. 149, R. 55, this Herman shore is marked by irregular swells and massive short ridges of gravel and sand, with occasional inclosed sloughs. This is succeeded by a half mile of the ordinary continuous single ridge, 1,147 to 1,150 feet.

Watercourse intersecting the beach near the northwest corner of Sec. 36, T. 149, R. 55, about 1,115 feet; bottomland 10 to 15 feet higher, a third of a mile wide, bordered by bluffs rising about 25 feet above it. Some portions of this creek are very shallow or dry, with scarcely any channel, but other portions are pools 6 to 9 feet deep and 20 feet wide, extending 10 to 20 rods or more.

Magnificent beach ridge, passing north-northwest through the east part of Secs. 26 and 23, T. 149, R. 55 (Lind), 1,147 to 1,150 feet. A road, which was formerly an Indian trail, runs on its top here and for several miles northward. This beach is composed of the usual sand and gravel, thickly filled with pebbles up to 2 and rarely 4 inches in diameter. It forms a broad wavelike ridge, 30 to 40 rods wide, including the slopes. On its west side is a depression of 5 to 10 feet, 20 to 60 rods wide, which is moist grass land, excepting a small reedy slough in the south edge of Sec. 11. Farther west undulating and rolling till rises to 1,175 feet within a quarter or a third of a mile and attains a height of 1,250 to 1,300 feet within 3 to 5 miles. On the east side of this upper Herman beach there is a very smooth slope descending 25 or 30 feet in as many rods. Next is a nearly level belt 20 to 60 rods wide, increasing in width from south to north, succeeded by a lower Herman beach ridge rising 8 to 10 feet, with its crest at 1,127 to 1,130 feet, or 20 feet below the upper beach. These parallel Herman beaches are very finely developed thus for nearly 6 miles, passing north through Secs. 23, 14, 11, and 2, T. 149, R. 55, and the southwest part of Sec. 35, T. 150, R. 55. High portion of the upper beach in the south edge of Sec. 14, 1,153 feet, and depression west, 1,142 feet; crest onward through this section, 1,153 to 1,149 feet. In the north part of Sec. 11 and the south edge of Sec. 2, it is a few feet lower, is irregular in height and outlines because of intersecting watercourses, and has a less continuous and shallower depression on its west side. In Sec. 2, however, both beach ridges are finely displayed, having the same contour as southward. Crest of upper beach in Secs. 2 and 35, 1,152 to 1,155 feet; depression on the west, 8 to 15 feet, partly occupied by a long slough. The northwest part of Sec. 35, in the course of these beaches, is lower smooth till, with no deposits of sand and gravel.

Goose River, near the north line of the NW. ¼ of Sec. 35, and the Little Goose River, in the north part of Sec. 15, T. 150, R. 55, where they cross the ancient lake shore, are in valleys about 30 feet deep, eroded in till. Each consists of pools 5 to 7 feet deep and 10 to 20 feet wide, alternating with other portions so narrow that one may step across them.

In the east part of the west half of Sec. 26 and the southwest corner

of Sec. 23, T. 150, R. 55, the upper Herman shore is offset a third of a mile east from the remainder of its course and consists of massive irregular swells of till, partly overspread with gravel and sand, 1,152 to 1,160 feet. Among them are hollows 4 to 6 feet deep without outlet, and their entire belt, a quarter of a mile wide, is crossed by depressions as low as 1,145 feet. Through Sec. 22 this shore bears a typical beach ridge of sand and gravel, 40 or 50 rods wide, 1,157 feet, with depression of 10 to 15 feet on the west; descent of eastern slope, 20 to 25 feet in 30 or 40 rods. In Sec. 15 this upper beach, 1,152 to 1,157 feet, has a quite irregular form, chiefly due to erosion by the Little Goose River and its small tributaries. It is again exhibited in its ordinary type through Sec. 10, being a ridge 25 or 30 rods wide, with crest at 1,155 to 1,157 feet, 15 to 20 feet above its east base, and with a narrow depression of 4 to 8 feet on the west; through the west part of Sec. 3, T. 150, R. 55, and the west edge of the SW. ¼ of Sec. 34, T. 151, R. 55, 1,157 to 1,159 feet, excepting gaps cut by small watercourses; and in the east edge of the NE. ¼ of Sec. 33, 1,154 to 1,157 feet. Thirty rods west from the northeast corner of this Sec. 33, its elevation is 1,155 feet, with slopes descending 12 feet eastward and 8 feet westward.

Lower Herman beach, a half mile to three-fourths of a mile east of the foregoing, in the west edge of Secs. 14 and 11 and the east edge of Sec. 3, T. 150, R. 55, 1,130 to 1,135 feet, from which there is a descent of 5 feet to its west base and 10 feet to the east. From the SE. ¼ of Sec. 34, T. 151, R. 55, this beach passes northeasterly to Larimore.

Upper Herman beach, a well defined ridge, running north through the east part of Sec. 28, T. 151, R. 55, 1,155 to 1,159 feet; thence north-northwesterly through Secs. 21 and 16, 1,157 to 1,160 feet, and through the southwest part of Sec. 9, the northeast of Sec. 8, and the SE. ¼ of Sec. 5, 1,157 to 1,162 feet. Where it is crossed by the Saint Paul, Minneapolis and Manitoba Railway from Larimore to Devil's Lake, in the south part of the NE. ¼ of Sec. 5, its crest was 1,162 feet, 4 feet above the track, and it holds the same height for about 50 rods northeastward. Two-fifths of a mile east from this beach the railroad crosses a second beach deposit whose crest and the track are the same, 1,146 feet.

SHORE WEST OF THE ELK AND GOLDEN VALLEYS.

Through Sec. 32, T. 152, R. 55 (Elm Grove), the upper beach runs northwesterly, its elevation being 1,160 to 1,163 feet. Its material is coarse gravel, with pebbles up to 6 inches in diameter, in part accumulated as a ridge 10 or 15 feet above the land at its base northeast and 5 to 8 feet above its southwest base, and in part lying on the flank of swells of very stony till, the crests of which are only 5 to 10 feet higher than the beach. This till or morainic drift contains a multitude of granitic and limestone bowlders up to 1½ feet in diameter, but few or none of larger size. In the rolling till which rises thence westward to

1,250 or 1,300 feet within 2 or 3 miles, are many granitic bowlders up to 5 feet or more in diameter, exceeding the usual proportion in the till of this region.

In the north edge of Sec. 32 and the south part of Sec. 29, T. 152, R. 55, this beach is the terracelike border of a nearly level tract of sand and gravel an eighth of a mile or more in width, at an elevation of 1,171 to 1,173 feet. The bordering slope is beach gravel, with its base at 1,155 to 1,158 feet; but the slow descent thence eastward is till, somewhat eroded by wave action and having many small and large granitic bowlders up to 4 or 6 feet in diameter strewn on the surface or partially covered by the soil. In the NE. ¼ of Sec. 30 this upper Herman beach is typically developed, being a gracefully rounded ridge of sand and gravel, 25 or 30 rods wide; crest, 1,165 to 1,166 feet; foot of eastern slope, 1,150 feet; depression west, usually 2 to 5 feet, beyond which is a slowly ascending area of smooth undulating till.

Upper beach through Sec. 19, T. 152, R. 55, a low rounded ridge of sand and gravel about 25 rods wide; crest, 1,166 to 1,168 feet; base of its east slope on the north line of this section, 1,158. In the SW. ¼ of Sec. 18, this beach is cut by the South Branch of the Turtle River; its elevation in this section south of the stream is 1,167 to 1,168 feet. There is no considerable valley here and the creek runs only in spring or after unusual rains, being reduced to stagnant pools during the rest of the year. Within 2 miles southeast, however, it becomes a living stream, fed by almost ice-cold springs; and thence to the secondary Herman beach, near Larimore, it has cut a valley 50 to 90 feet deep.

Elm Grove, comprising about 5 acres, is on this creek, a third of a mile east of the upper Herman shore line, which continues north-northwestward through the southwest part of Sec. 18, T. 152, R. 55, and the northeast edge of Sec. 13, T. 152, R. 56 (Niagara), to the west side of Little Elm Grove, 10 acres or more in extent, in the east part of Sec. 12. Along this distance of 1½ miles the surface presents a very favorable slope from 1,150 to 1,200 feet elevation, on which a beach ridge or definite beach deposits would usually be found well developed; but the waves and currents of Lake Agassiz could not act very efficiently here, because this area lay in the lee of islands and a wave-formed bar or beach several miles to the east, which are the eastern boundary of the Elk Valley. Consequently deposits of beach sand and gravel are scanty on the upper western shore of Lake Agassiz here and for 40 miles northward along the extent of the Elk and Golden Valleys, east of which a narrow chain of islands and bars rose above the surface of Lake Agassiz during its highest Herman stage. Between the South Branch of Turtle River and Little Elm Grove the beach formation consists only of a thin covering of sand and gravel spread on the sloping area of till, elevation from 1,160 to 1,175 feet. Several of the small grassy channels eroded here, dry excepting in spring and times of excessive rain,

are almost completely paved with stones up to 1 or 2 feet in diameter, but few stones occur upon the adjoining surface of till.

From the Little Elm Grove the highest western shore of Lake Agassiz (consisting of a similar slope of till ascending gently westward, with inconspicuous deposits of beach gravel and sand, not accumulated in any distinct ridge, but probably recognizable almost continuously) extends northward through Secs. 12 and 1, T. 152, R. 56, and Secs. 31 and 30, T. 153, R. 55 (Agnes), to the central part of Bachelors' Grove, which it passes through in the west half of Sec. 30. This grove borders the head stream of Turtle River for 1½ miles, with an average width of about a quarter of a mile, thus comprising approximately 250 acres. It is dense woods, chiefly elm and basswood in its east half, but nearly all bur oak for the west half. Much bur oak is also found along several miles of this stream next westward, but it is not seen from the margin of Lake Agassiz, being hidden in the valley, 40 to 50 feet deep, which the stream has eroded in that area of undulating and rolling till.

Surface at M. S. Wallace's house, in the middle of the west edge of Sec. 32, T. 153, R. 55, 1,146 feet. Bridge over the North Branch of Turtle River on the east line of the SE. ¼ of Sec. 30, 1,150 feet; channel (dry August 5, 1885), 1,142 feet. There is no valley here, only a trenchlike channel in the flat expanse of Lake Agassiz, 8 feet deep.

Herman beach, for the first mile or more north from Bachelors' Grove, passing through the NW. ¼ of Sec. 30 and the west edge of Sec. 19, 1,165 to 1,170 feet. This is mostly a well defined beach ridge, 20 to 30 rods wide, composed of sand and gravel, with pebbles up to 2 inches in diameter. It rises slowly to a height of 10 or 12 feet above the flat land on the east and is bordered on the west by a depression of 1 to 3 feet, beyond which a smoothly undulating and rolling surface of till rises to an elevation of 1,200 and 1,250 feet at a distance of 3 miles. In the NW. ¼ of this Sec. 19 the beach deposit becomes complex, consisting of several irregular ridges rising 5 to 8 feet above their bases, 1,167 to 1,170 feet above sea level, with inclosed hollows, and the depression close west occasionally sinks to 1,155 feet.

Surface at Michael McMahon's house, 40 rods west from the center of Sec. 13, T. 153, R. 56 (Oakwood), 1,176 feet. Rounded hill of till a half mile northeast, about 1,205 feet; swells of till in the southwest part of Secs. 12 and 2, 1,195 to 1,210 feet.

Through these Secs. 13 and 12, the southwest part of Sec. 1, and in Sec. 2, T. 153, R. 56, to the grove on the north line of this section at the junction of the north and south branches of Lost Creek, and thence northeast and north through Sec. 35, T. 154, R. 56 (Elksmount), the Herman shore, between 1,160 and 1,170 feet, is not marked by any considerable deposits of gravel and sand. Farther north this shore is distinguished not only by a noticeable change in the topographic features along a nearly level line at 1,170 feet, dividing the very flat area of the glacial lake from the undulating and rolling till on the west, but also

by occasional beach deposits. Through the south half of Sec. 26 a somewhat typical beach ridge of sand and gravel, 15 to 25 rods wide, with a depression of 3 to 6 feet on its west side, runs north and northwest, its crest being at 1,175 to 1,170 feet, declining from south to north. On the east its slope falls 5 to 10 feet in 10 to 20 rods; and thence a more gentle descent, with surface of sand and fine gravel, sinks to 1,155 feet within an eighth of a mile. In the NW. ¼ of this Sec. 26 the beach ridge ceases and is succeeded northward by an expanse of nearly flat till, which along the north line of this section sinks eastward from 1,175 to 1,155 feet.

Elk Valley, for 12 miles from Elm Grove and McCanna north to Forest River, is nearly constant in elevation, which is 1,155 feet on its west border and 1,135 feet near its east side, its average width being about 4 miles.

Surface at Frank Hamilton's house, in the center of the NE. ¼ of Sec. 15, T. 154, R. 56, 1,178 feet.

Upper Herman beach, a definite and massive ridge of sand and fine gravel, 25 to 40 rods wide, for a half mile south from the South Branch of Forest River, in the west part of the NW. ¼ of Sec. 14, T. 154, R. 56, 1,173 to 1,178 feet, passing north and northwest, with a descent of 12 to 15 feet on the east and a depression of 4 to 8 feet on the west.

Beyond this branch of the Forest River, in the north half of Sec. 10, the beach ridge, similar in outline, with its crest at 1,174 to 1,179 feet, is the site of an abandoned railway grade, on account of which its material is well exhibited. It is sand and gravel, and three-fourths of the pebbles, mostly less than 2 inches in diameter, are dark gray slaty shale. Twenty miles to the south-southeast the same shale in small grains makes fully two-thirds of a stratum of sand that extends from 20 to 60 feet in depth in the well at the Sherman House, Larimore. Pebbles of it were also observed in kamelike deposits of gravel and sand near Balaton, Lyon County, in Southwestern Minnesota. During the further exploration of the western shore of Lake Agassiz this shale was discovered in place and is found to be the bed rock, of cretaceous age, which forms the conspicuous escarpment of Pembina Mountain, though even there it is generally covered and concealed by drift.

Natural surface at the northwest corner of Sec. 3, T. 154, R. 56, on the line between Grand Forks and Walsh Counties, 1,181 feet.

The upper Herman shore passes north-northwesterly through this corner of Sec. 3 and the east part of Sec. 33, T. 155, R. 56 (Medford), to the Middle Branch of Forest River (farther east formerly called Salt River), which it reaches near the center of the east half of Sec. 28. It has only scanty deposits of beach gravel and sand, nowhere forming a ridge; instead, the surface is mainly till, very flat east of this shore, but undulating or rolling westward.

The South and Middle Branches of Forest River occupy valleys 25 to 40 feet deep and 20 to 30 rods wide. They are bordered with groves,

or at least a continuous line of trees, along the greater part of their course.

In the NW. ¼ of Sec. 28 and the west part of Sec. 21, T. 155, R. 56, the highest shore line of Lake Agassiz is very distinctly marked, at 1,183 to 1,185 feet, by being the upper edge of a flat slope of till, probably with scanty deposits of gravel and sand, which sinks 20 to 30 feet in the next half mile eastward. Farther east, for the width of 3 or 4 miles across the Elk Valley, the surface elevation is 1,160 to 1,125 feet.

Just west of this shore line a knolly belt of morainic drift, bearing a marvelous profusion of bowlders, occupies a width of 25 to 50 rods, generally forming a single series of hillocks rising 15 to 30 or 35 feet. These are strewn with bowlders of all sizes up to 5 feet and rarely 8 feet in diameter, so plentiful that they cover a third or even half of the surface. A few masses of limestone were observed; but fully 99 per cent. of the bowlders are archean granite and gneiss. This is the most eastern portion of a semicircular moraine, which appears to have been accumulated on the eastern boundary of a lobe of the ice sheet during a pause in its retreat. From Secs. 21 and 28 this moraine continues, with nearly the same features, south and southwest to the SE. ¼ of Sec. 32, and thence west-southwest by Pilot Knob in the NW. ¼ of Sec. 5, T. 154, R. 56, to the west side of Sec. 1, T. 154, R. 57, and perhaps beyond. Its hills and knobs rise 25 to 75 feet above the general level of the adjoining smoothly undulating till, their tops being 1,250 to 1,300 feet above the sea. To the north, northwest, and west it reaches, with similar development, in a great curve convex to the northeast, along an extent of 5 or 6 miles, to a cluster of prominent morainic hills rising 50 to 75 feet, situated in Secs. 2 and 3, T. 155, R. 57. This moraine matter was doubtless englacial; among its multitude of both large and small rock fragments a half hour's search failed to discover any marked with striæ or having surfaces planed by glaciation. On the west the area inclosed by this curving moraine is very smooth, only slightly undulating till, at 1,185 to 1,250 feet, ascending slowly westward.

Another distinct morainic series, similar in its very knolly contour, in its material (excepting a larger proportion of gravel, half of which is the cretaceous shale before described), and in the great abundance of bowlders, nearly all granitic, branches from the preceding in the north part of Sec. 8, T. 155, R. 56, and sweeps northeast and north through the west half of Sec. 4, and thence northwest and west through Secs. 32, 29, and 19, T. 156, R. 56 (Vernon), and Secs. 13 to 16, T. 156, R. 57 (Norton), to a group of morainic hills about 75 feet high, a mile northwest of Galt post office. Between this curved moraine and the nearly parallel northern part of the preceding, 4 miles distant to the south, the surface is very smooth undulating till, rising slowly toward the west.

These moraines, with their east base at 1,185 to 1,170 feet above the sea, formed the west shore of Lake Agassiz at its highest stage for nearly 7 miles between the Middle and North Branches of the Forest

River. The North Branch intersects this shore line near the center of Sec. 20, T. 156, R. 56, close to the southwest end of Ramsey's groves, which extend thence about a mile along this watercourse in the north part of Sec. 20 and the SE. ¼ of Sec. 17. The stream in these sections has no valley, only a channel 20 to 30 feet wide and 10 feet deep.

Elevation of road at the southeast corner of this Sec. 20, 1,177 feet.

Golden Valley, on the north line of Secs. 4 and 5, T. 156, R. 56, 1,185 to 1,195 feet, showing an ascent of 10 feet from east to west in its width of 2 miles. About the same transverse slope, raising the west side of this valley 10 or 15 feet above its east side, is found along its whole extent of 20 miles or more, from the Middle and North Branches of Forest River to the Middle and North Branches of Park River. In the north half of T. 156, R. 56, and thence northward, the width of this valley varies from 1¾ miles to only 1 mile. It is flat and consists mainly of clay, free from gravel; but wells find gravel intermixed with the clay, probably till, at a depth of a few feet, and about 20 feet from the surface they sometimes encounter a water-bearing stratum of gravel, chiefly made up of cretaceous shale.

Natural surface at the southwest corner of Sec. 27, T. 157, R. 56 (Garfield), 1,191 feet. Highest part of Golden Valley south of the South Branch of Park River, along the north line of Secs. 27, 28, and 29, in this township, 1,199 feet on the east to 1,211 feet on the west. Surface at school-house on the west side of the NW. ¼ of Sec. 21, 1,207 feet.

South Branch of Park River at the Garfield bridge, near the middle of the north line of Sec. 21, T. 157, R. 56, 1,170 feet, approximately; bottomland about a quarter of a mile wide, 10 to 15 feet above the stream; crest of the south bluff rising to the flat belt of the Golden Valley, 1,191 to 1,209 feet, ascending westward; of the north bluff, 1,189 to 1,205 feet.

Golden Valley, on the north line of Sec. 5, T. 157, R. 56, 1,195 to 1,205 feet; 2 miles farther north, on the north line of Sec. 29, T. 158, R. 56 (Lampton), 1,198 to 1,208 feet. In this northern part of the valley limited tracts of its flat area are strewn with abundant bowlders up to 2 feet and less frequently 3 or 4 feet in diameter. They are probably where swells of till rose nearly to the surface of the water in this strait of Lake Agassiz, so that its fine portions were swept away by waves and currents, to be deposited elsewhere in the valley as clayey silt, leaving the masses of rock which could not be thus removed. Approaching the Middle Branch of Park River, the surface of Golden Valley continues very smooth and flat, but it ceases to have a continuous ascent from east to west, some portions along the center being depressed a few feet. Such a shallow hollow holds a slough about a mile long from south to north and a half mile wide in its broadest part, at 1,193 feet, extending from the north edge of Sec. 20 through the west part of Sec. 17, T. 158, R. 56, in which a small area of water remains throughout

the year. On each side of this slough and for miles south and north, this valley is a great hay meadow.

The west border of the Golden Valley was the most western shore of Lake Agassiz in its highest stage, but it is only very scantily marked by deposits of beach gravel and sand, because of its sheltered position on the western and leeward side of this narrow strait. From the middle of Sec. 20, T. 156, R. 56, this shore line extends in a quite direct course a few degrees west of north 11 miles through the west part of Secs. 17, 8, and 5, in this township, Secs. 32, 29, 20, 17, 8, and 5, T. 157, R. 56, and the east edge of Secs. 31 and 30, T. 158, R. 56. For the next 3 miles, in the east edge of Secs. 19, 18, and 7, T. 158, R. 56, it runs nearly due north. Thence it turns to a northwesterly course through Sec. 6 of this township, passing a mile west of Edinburgh post office and through Sec. 31, T. 159, R. 56. In this vicinity the Golden Valley terminates.

Bushes and trees clothe the slope on the west side of the Golden Valley along its northern part, extending to the south line of T. 158, R. 56; but this ascent farther south, also the entire extent of the Golden Valley, the drift hills forming its east border, and the vast plain of the Red River Valley, are prairie, excepting that narrow belts of timber border the water courses.

Smoothly undulating till rises slowly from the west side of the southern part of the Golden Valley; but in Sec. 30, T. 158, R. 56, rounded hills of till attain a height about 100 feet above the valley, or 1,300 feet above the sea. Thence northward a smooth slope ascends 50 to 60 feet, or in some portions only 30 or 40 feet, within the first quarter or half of a mile to the west, succeeded beyond by a moderately rolling surface with less ascent.

A terrace of beach sand and gravel, containing pebbles and cobbles up to 6 inches in diameter, extends a third of a mile from southeast to northwest, with a width of 5 to 30 rods, in the NW. ¼ of Sec. 33, T. 158, R. 56, abutting on the west flank of the rolling and hilly deposits of till which make the east border of the Golden Valley. It was formed by currents entering this strait of Lake Agassiz from the north, eroding the bordering hills in the east edge of Secs. 20 and 29, and thence sweeping this sand and gravel southward. It marks the highest stage of Lake Agassiz, having an elevation of 1,213 to 1,195 feet, declining from north to south, and also sinking 1 or 2 feet from west to east in its width of 100 to 500 feet, being thus slightly higher along its verge than where it rests upon the adjoining hilly till.

Natural surface at the quarter-section stake on the east side of Sec. 8, T. 158, R. 56, 1,203 feet; at Edinburgh post office, near the center of Sec. 5, 1,202 feet.

Middle Branch of Park River a half mile south of Edinburgh, approximately, 1,185 feet; crest of the south bank of the very small valley of this stream, rising to the flat Golden Valley, 1,192 feet on the east to

1,215 feet on the west. The Golden Valley here shows thus a transverse ascent of more than 20 feet in its width of about 1 mile. On the north line of Secs. 5 and 6, T. 158, R. 56, the east edge of this valley has an elevation of 1,210 feet, and its west edge, 1,220 feet. About a half mile farther north, the height of this belt, where it is crossed by a tributary of the Middle Branch, is 1,220 to 1,235 feet, from east to west, being thus above the highest level of Lake Agassiz. Elevation of this tributary at a bridge of a road that runs very crookedly through bushes and small woods in Sec. 32, T. 159, R. 56, 1,204 feet; and at a bridge a few rods north of the middle of the east side of Sec. 29, 1,175 feet.

BEACHES AND ISLANDS EAST OF THE ELK AND GOLDEN VALLEYS.

Returning about 45 miles south to Larimore, we have yet to describe the beaches of Lake Agassiz and its islands of rolling and hilly till which divided the strait of the Elk and Golden Valleys in Grand Forks and Walsh Counties from the main body of this glacial lake.

Saint Paul, Minneapolis and Manitoba Railway track at Larimore, 1,134 feet above the sea.

The upper or first and the second Herman beaches before described, respectively 4⅜ and 4⅛ miles west of Larimore, are 1,162 and 1,146 feet above the sea. Third Herman beach, a third of a mile east of Larimore depot, crest, 1,133 feet; another beach belonging to the same stage of Lake Agassiz, a third of a mile farther east, crest, 1,134 feet, with descent in thirty or forty rods east 11 feet, and in the same distance west 9 feet. Fourth Herman beach, consisting of four small beach ridges crossed by the railway 1½ to 2 miles east of Larimore, crests, 1,123 to 1,118 feet, with intervening hollows 3 to 5 feet deep. A nearly level tract reaches 4 miles westward from Larimore along the railway to Devil's Lake, averaging 1,130 feet and varying only 2 or 3 feet above and below this level. Beneath the rich black soil here and elsewhere, all about Larimore, are stratified sand and fine silt free from gravel. The beach ridges near this town are consequently composed wholly of sand, quite in contrast with their usually coarser material.

Well at the Sherman House, Larimore, L. C. Neal, proprietor, dug 20 feet and bored 40 feet lower: soil, 2 feet; fine sandy and clayey silt, without coarse sand, gravel, or stones, 5 feet; fine yellowish sand, with less clay, being mainly siliceous, 13 feet; and dark sand, very soft to bore through, two-thirds cretaceous shale in particles up to a twentieth of an inch in diameter, 40 feet, with much water. Hard blue till was found at the bottom. This is the deepest well in the town. All the other wells are said to obtain their supply of water at a depth of about 20 feet, in the upper part of this sand chiefly derived from shale. The origin and manner of deposition of these beds of sand and silt deserve further observations and study.

The beach seen two-thirds of a mile east of Larimore passes north and north-northwesterly through the east half of Secs. 7 and 6, T. 151, R. 54, and the west half of Secs. 31 and 30, T. 152, R. 54, into the southeast corner of Sec. 24, T. 152, R. 55. North of the South Branch of Turtle River it is not a typical ridge, but a series of massive rounded swells of sand 10 to 15 feet high, with their crests at 1,135 to 1,140 feet.

A parallel beach ridge a third to a half mile west of the foregoing, mostly massive, with typical wavelike form, has an elevation of 1,133 feet close east of Larimore; 1,144 feet at a cemetery close north of the South Branch of Turtle River in or near the southwest corner of Sec. 31, T. 152, R. 54; chiefly 1,137 to 1,140 feet in its course thence north-northwesterly through Secs. 36 and 25, the west edge of Sec. 24, and the east half of Sec. 14, T. 152, R. 55; 1,142 to 1,145 feet in the west half of Sec. 11 and 1,143 to 1,147 feet in the east edge of Sec. 3 of this township. Along the west edge of Sec. 11, a duplication of this beach ridge, of the same massive size, lying a half mile farther west, extends a mile south from the North Branch of Turtle River, its crest being at 1,142 to 1,145 feet; but thence southward the general elevation is about 1,130 feet to the tract of this height crossed by the railway west of Larimore, excepting that the South Branch of Turtle River has eroded a valley 40 to 75 feet deep. The distance of one and a half miles from Larimore north to this stream is a gradually descending smooth slope, but its northern bluff rises steeply to a height a few feet above that of Larimore.

North Branch of Turtle River in the north half of Sec. 11, T. 152, R. 55, 1,085 to 1,075 feet; bottomland, an eighth of a mile wide, 10 to 15 feet above the stream; crest of bluffs a quarter to a third of a mile apart, about 1,135 feet.

Saint Paul, Minneapolis and Manitoba Railway at McCanna, 1,140 feet; on bridge over the North Branch of Turtle River, 1,132 feet, 17 feet above the stream; summit, in the northeast corner of Sec. 22, T. 153, R. 55, grade and natural surface, 1,164 feet; Orr, 1,098 feet.

Lower Herman beach, running northwesterly in the northeast part of Sec. 24, T. 152, R. 55, 1,127 to 1,128 feet, with depression of 2 to 3 feet on its west side; in Sec. 13, 1,127 to 1,132 feet; in the west part of Sec. 12 and the northeast part of Sec. 11, 1,130 to 1,135 feet, being in these sections the easternmost in a succession of three beach ridges, the two others of which are 10 feet higher; at E. C. D. Shortridge's house, in the center of Sec. 2, 1,137 feet, forming a broad flat swell of sand and fine gravel, with a depression of 3 to 5 feet on its west side; in the west part of Sec. 36, through Secs. 26 and 23, and the southwest edge of Sec. 14, T. 153, R. 55, a continuous, well defined beach ridge, 1,140 to 1,149 feet, with a descent of 10 to 15 feet on the east and a depression of about 5 feet on the west; in the east edge of the NE. ¼ of Sec. 15 and through the SE. ¼ of Sec. 10, a deposit of sand and fine gravel, with nearly level top 20 to 30 rods wide, 1,145 to 1,149 feet, from which a slope falls 10 or 15 feet in 20 to 30 rods eastward, while on the west it is bordered

by a slough 5 to 20 rods wide, which is partly permanent water and partly mowing land. It is to be noted that the northern two-thirds of the beach here described for a distance of 8 miles corresponds in elevation with the two beaches close east of Larimore and their continuation northward to the North Branch of Turtle River, marking the third Herman stage of Lake Agassiz; but that the southern part records a slightly lower level of the lake, when it had fallen about 10 feet, or to its fourth Herman stage.

On the west side of this beach a smoothly undulating broad swell of till, which was an island in Lake Agassiz, lies in the west part of Sec. 26 and the east edge of Sec. 27, T. 153, R. 55, with nearly level top of several acres, at 1,182 to 1,190 feet. An aboriginal burial mound, raised 4 feet and 50 feet across, is situated on the highest part of this area, 15 rods east-northeast from the quarter-section stake between these sections. Such localities, overlooking an extensive and beautiful panorama, were frequently chosen for this use, as is shown by many mounds on hill-tops and on the margin of bluffs bordering deeply eroded valleys throughout the Northwest. A lower tract of somewhat roughly rolling till, with plentiful bowlders, reaches a third of a mile southeasterly from this swell to the south edge of Sec. 26. Thence a broad ridge of beach gravel and sand, belonging to the second and third Herman stages of Lake Agassiz, with an elevation of 1,153 to 1,151 feet, sinking southward to 1,145 feet, extends south-southeasterly through the east half of Sec. 35 and continues with the same course to Larimore, as before described.

North of this island the upper Herman beach is represented in the east part of the SE. ¼ of Sec. 22 and in the west half of the SW. ¼ of Sec. 23, T. 153, R. 55, by a wide tract of gravel and sand deposits, in irregular ridges and swells rising 4 to 8 feet, mostly trending from north to south, with their crests at 1,164 to 1,170 feet. Next to the north it is a well defined beach ridge, with crest rising from 1,163 to 1,168 feet in its course of a half mile from south to north through the east edge of the NE. ¼ of Sec. 22.

In the SE. ¼ of Sec. 15, T. 153, R. 55, the plain that descends slowly toward the Red River on the east is divided from the Elk Valley on the west by a low swell of till, having an elevation of 1,157 to 1,160 feet, destitute of beach deposits. This is succeeded in the north part of this section and the south part of Sec. 10 by a second island which rose above the highest level of the glacial lake, having a length of 1 mile from south to north and averaging a quarter of a mile wide, its elevation in the SW. ¼ of the NE. ¼ of Sec. 15 being about 1,187 feet, on the line between these sections about 1,175 feet, and near the center of Sec. 10, at the north end of this irregular ridge, about 1,180 feet. Its material is till, partially overspread in its south half by gravel, which seems to have been brought by the currents and waves of Lake Agassiz from the erosion of its northern portion.

The beach of Lake Agassiz during its highest stage extends north from the north end of this island into the SW. ¼ of Sec. 3, T. 153, R. 55, where it is a ridge about 20 rods wide, with an elevation of 1,165 to 1,172 feet, composed of coarse gravel and sand, inclosing plentiful rock fragments, chiefly granitic, of all sizes up to 6 inches in diameter, most of which are only slightly water-worn. Its eastern slope descends 15 to 20 feet in as many rods, and on the west an equal descent takes place within 8 or 10 rods. The steep western slope of this beach or bar, forming the east rim of the strait that filled the Elk Valley, was due to storms on the broad lake, rolling its waves upon the bar and carrying the sand and coarse gravel upward and over its crest. Turning northwestward, this beach passes into the NE. ¼ of Sec. 4, where it consists of irregular accumulations of gravel and sand, occupying a width of an eighth to a fourth of a mile, with their crests at 1,155 to 1,162 feet. In the north edge of Sec. 4 it again becomes a definite beach ridge of the same material and contour as in Sec. 3, and thus passes northeast and north through Sec. 33, T. 154, R. 55, with its crest mostly at 1,165 to 1,172 feet, its lowest part, about 1,162 feet, being near the center of this section. The two islands before described, this beach or bar, and the long island next northward are together commonly called "The Ridge," being the eastern limit of the Elk Valley, which averages 4 miles wide, 1,150 to 1,140 feet above the sea in its eastern and central portions, but rising with a transverse slope to 1,160 feet on its western border.

A third island above the highest stage of Lake Agassiz, 3 miles long from south to north and a quarter to a half mile wide, reaches through the central part of Secs. 28 and 21, the west half of Sec. 16, and into the southwest corner of Sec. 9, T. 154, R. 55. It is till, with somewhat uneven surface, bearing frequent bowlders. Highest points of this in Secs. 28 and 21, 1,185 to 1,195 feet; intervening gaps, about 1,170 feet; summit, near the center of the SW. ¼ of Sec. 18, 1,223 feet, and lower summit, about a half mile to the north, 1,218 feet, each bearing a flat round earthwork about 1 foot higher; lowest depressions intervening, about 1,195 feet; depressions in the northwest part of Sec. 16, 1,185 feet, and highest points in the southwest corner of Sec. 9, 1,194 and 1,195 feet. Beach deposits occur on the east flank of this island in Sec. 21 at 1,155 to 1,165 feet, and from 1,155 feet a smooth slope of sand and fine gravel falls slowly eastward along the east side of this highland through the greater part of its extent.

In the southeast part of Sec. 8, T. 154, R. 55, irregular accumulations of beach gravel, with crests at 1,170 to 1,175 feet, 10 to 15 feet above the adjoining depressions of till, extend northward from the island just described; and in the north part of this Sec. 8 the beach sinks within an eighth of a mile from 1,172 to 1,161 feet and changes to a broad, smooth ridge, which thence passes northward through Sec. 5 of this township, in which it is intersected by the Forest River, with valley a half mile wide and 60 to 75 feet deep, and through the west

half of Sec. 32, T. 155, R. 55, near the center of which it has three aboriginal mounds on its top. The material of this beach ridge is fine gravel and sand. Elevation of its crest on the line between Secs. 8 and 5, 30 to 40 rods east of the quarter-section stake, 1,161 feet; an eighth of a mile north, at the verge of the south bluff of Forest River, 1,155 feet; for the first half mile from the bluff north of this river, 1,152 to 1,157 feet; and at the mounds in Sec. 32, 1,156 to 1,159 feet. These mounds lie in a line bearing north-northeast; top of most southerly mound, 1,162 feet, about 6 feet above the adjacent ground; elevation of the middle one, some 20 rods away, 1,166 feet, and of the most northern, again about 20 rods from the last, 1,167 feet, each being 8 feet higher than its base.

Another beach ridge, 20 rods wide, with descent of 10 feet on each side in as many rods, formed during the same stage of Lake Agassiz, lies a half to three-fourths of a mile west from the foregoing, in the NE. ¼ of Sec. 6, T. 154, R. 55. This is the highest land between the main Forest River and its South Branch. It consists of sand and fine gravel, of which a considerable proportion (about a sixth) is cretaceous shale. The maximum elevation of this ridge, 1,157 to 1,164 feet, is maintained for 50 or 60 rods, from which it sinks to 1,150 feet at each end.

From the north side of Sec. 32, T. 155, R. 55, an island of rolling and hilly till above the highest level of Lake Agassiz, far larger than any of those already described, extends, with the exception of two short gaps, 20 miles northward, varying in width from a half mile to a little more than 1 mile in its southern quarter and from 1½ to 2½ miles through the remainder of its extent. This hilly tract, commonly denominated "the mountains," forms the east border of the Golden Valley. In the north part of Sec. 36, T. 156, R. 56, it has a depression to about 1,180 feet, which probably was a strait of the glacial lake in its highest stage, an eighth of a mile wide and a few feet deep. Again, in the center of T. 157, R. 56 (Garfield), it is intersected by the South Branch of Park River, which has a valley a quarter to a half of a mile wide and about 75 feet deep. The stream, in its course of 1½ miles through this belt, descends about 50 feet, from 1,165 to 1,115 feet, approximately. It seems almost certain that a depression slightly lower than the Golden Valley on the west originally extended across this rolling and hilly area where it is cut by this South Branch of Park River; but the erosion of its valley has undermined and removed portions of adjoining hills and ridges, so that its inclosing bluffs now rise 50 to 100 feet, their highest points being about 1,225 feet above the sea, or 25 to 30 feet above the east edge of the Golden Valley. All these bluffs and two plateaus left in the midst of the valley are till, yellowish near the top and dark bluish below.

Elevation of "the mountains" in their southern and narrower portion, through the west part of T. 155, R. 55, and the northeast corner of T.

155, R. 56, 1,190 to 1,225 feet; through the east half of T. 156, R. 56, 1,200 to 1,250 feet; in the south part of T. 157, R. 56, 1,200 to 1,260 feet; and through the north half of this township and the south half of T. 158, R. 56, 1,200 to 1,275 feet, being highest in Sec. 28 of the township last named, near the northern end of this hilly tract.

The east border of "the mountains" in Sec. 20, T. 155, R. 55, falls somewhat steeply to about 1,135 feet, and thence a flat slope, with no beach ridges, sinks slowly eastward. In the NW. ¼ of the NE. ¼ of Sec. 7 in this township a well defined beach ridge 10 to 15 rods wide, composed of sand and gravel, with pebbles up to 2 or 3 inches in diameter, extends 25 rods south from an eastern spur of the hilly till; crest of this spur, about 1,195 feet; of the beach, 1,172 feet, with depression of 3 to 6 feet on the west. Irregular beach accumulations, 10 to 20 feet lower, continue southward nearly a half mile. The east half of Sec. 6, T. 155, R. 56, has a descent of nearly 100 feet to about 1,100 feet. It is till, with no noteworthy beach deposits. No stream has flowed through the depression in Sec. 36, T. 156, R. 56, and no considerable watercourse crosses the gentle slope of till, overspread with much beach gravel at 1,175 to 1,155 feet, which lies within the next mile east.

In Sec. 30, T. 156, R. 56, the eastern border of this rolling and hilly area falls 75 feet or more within a third of a mile, to about 1,100 feet. Its material is till, with scanty deposits of beach gravel and sand, not distinctly accumulated in ridged form. About half way down this slope, it shows in some places a more abrupt escarpment, with steep descent of 15 or 20 feet. The same features continue through Sec. 19, except that a series of distinct beach deposits is observable about 25 rods east from the crest of the slope, at 1,170 to 1,175 feet, probably formed during the second Herman stage of Lake Agassiz. A little farther north, the upper Herman beach is probably represented, 15 to 30 rods north-northeast from the southwest corner of Sec. 18, in a bank of coarse gravel at 1,182 feet, with a small coulée on its west side. A descent of 125 feet takes place within a half mile on the east side of "the mountains," near where it is cut by a large but short ravine, in the SE. ¼ of Sec. 12, T. 156, R. 56, falling from 1,180 to 1,050 feet, approximately, with no well marked shore lines observable. A grove lies at the east base of this slope a third of a mile south of the ravine. In the NW. ¼ of this Sec. 12 and the west edge of the SW. ¼ of Sec. 1, a well developed beach, in part consisting of two parallel low ridges, has an elevation of 1,170 to 1,177 feet; and in the east edge of Sec. 2, continuing northward, its elevation is 1,177 to 1,184 feet. Its eastern slope falls to 1,170 feet within 10 or 20 rods. Through Sec. 36, T. 157, R. 56, it is not very distinct; but 10 to 25 rods north from the quarter-section stake between Secs. 36 and 25 it is represented by a broad bank of gravel and sand, with crest at 1,187 to 1,190 feet, from which a slight depression falls 1 or 2 feet on the west.

Saint Paul, Minneapolis and Manitoba Railway track at Park River depot, 998 feet; natural surface at the southeast corner of Sec. 23, T. 157, R. 56, on the road from Park River to Garfield, 1,178 feet.

Crest of the upper Herman beach crossed by this road 10 rods west from the point named, 1,187 feet; same 20 rods southeast and northwest from the road, 1,192 feet; depression on the west 3 to 8 feet and descent on the east 10 to 15 feet in as many rods. This is a typical beach ridge of sand and gravel, with pebbles up to 2 or 3 inches in diameter, mostly limestone and granite. The cretaceous shale before mentioned is very rare in the till of "the mountains" and in the beaches formed along their east side, indicating that the east limit of this shale is the Pembina Mountain and the western ascent of the Golden Valley, and that the glacial currents by which the drift here was deposited came only from the north and northeast, with no intermixture of currents from west of north.

Highest beach on verge of south bluff of the South Branch of Park River, in the SE. ¼ of Sec. 23, T. 157, R. 56, 1,188 to 1,192 feet, with a basin shaped hollow on its west side 20 feet lower, which changes southward to a depression of about 5 feet. The river bluff is here freshly undermined, showing the depth of the beach sand and gravel to be 5 to 10 feet, lying on till. Lower beach, a quarter of a mile farther east, extending from northwest to southeast, in the SW. ¼ of Sec. 24, 1,167 to 1,170 feet.

Lower Herman beach, a massive ridge of gravel and sand, extending in a curved course convex toward the east from the NE. ¼ of Sec. 2, T. 157, R. 56, through the southeast part of Sec. 35, T. 158, R. 56, crest, 1,160 to 1,165 feet; through the northeast edge of Sec. 36 and the southwest corner of Sec. 25, 40 to 50 rods wide, with slightly undulating surface, 1,160 to 1,167 feet; near the middle of the east side of the SE. ¼ of Sec. 26, 1,165 to 1,166 feet; and at the quarter-section stake on the north side of this Sec. 26, 1,163 feet.

Near the west line of Sec. 23, T. 158, R. 56, two Herman beaches abut upon the east flank of the north end of "the mountains," and extend thence north-northwesterly 2 miles to the Middle Branch of Park River. The eastern one, a well defined ridge of sand and fine gravel, passes close west of the quarter-section stake between Secs. 15 and 10. The elevation of its crest is 1,161 to 1,166 feet, with increase in height from south to north; the descent on the east is 15 or 20 feet in as many rods, and the depression on the west is 3 to 8 feet deep and 10 rods wide. The other beach ridge is 40 or 50 rods farther west, parallel with the preceding and similar in form and material; its crest, rising slightly northward, is at 1,173 to 1,176 feet. Another distinct beach ridge, but of smaller size, runs in a parallel course through the east part of the SW. ¼ of Sec. 9, with its crest at 1,185 to 1,187 feet. These appear to represent in succession the fourth, third, and second Herman beaches

of the series observed northwest of Maple Lake in Minnesota and east and west of Larimore.

Upper Herman beach, northward from the north end of "the mountains," forming in the NW. ¼ of Sec. 21 and the west part of Sec. 16, T. 158, R. 56, a massive, broad ridge, composed of sand and gravel, with pebbles up to 4 or even 6 inches in diameter, crest, 1,197 to 1,207 feet, rising highest northward, where the beach deposit overlies the eastern slope of a wavelike swell of till that rises to 1,212 feet. Small beach ridge, belonging to this stage, in the east edge of the SE. ¼ of Sec. 8, 1,202 to 1,207 feet. Surface at Evan Edwards's house, in the west part of the SW. ¼ of Sec. 9, 1,197 feet, consisting of sand and gravel of this beach to a depth of 10 feet, underlaid by till, yellowish in its first 6 feet and dark bluish below. Summit of a smoothly rounded hillock, probably till, but having few or no bowlders, in the east edge of the NE. ¼ of Sec. 8, about 1,230 feet; train of beach gravel and sand extending thence 30 rods southward, 1,217 feet, with descent of 15 or 20 feet on each side.

Continuing beyond the Middle Branch of Park River, this highest beach is well developed in a broad ridge running due north through the west part of Sec. 4, T. 158, R. 56, with its crest at 1,202 to 1,208 feet. On the east the surface falls 30 or 40 feet, and more slowly beyond, while toward the west a descent of 10 feet is succeeded by a flat surface of till, which rises slowly from the foot of the beach ridge to a swell, 1,215 to 1,225 feet, a half mile away, forming the east boundary of the Golden Valley. This beach is sand and gravel, with pebbles up to 6 inches in diameter. About half of them are limestone; nearly all of the remainder are archean granite, gneiss, and schists; scarcely 1 in 200 is cretaceous shale. Through the west edge of Sec. 33, T. 159, R. 56, the elevation of this excellent beach ridge is 1,202 to 1,205 feet, and in the southwest edge of Sec. 28 and the middle of the east edge of Sec. 29, 1,202 to 1,197 feet, decreasing in height and size northward. For a half mile through the SW. ¼ of Sec. 33, a slight secondary beach ridge, 4 to 9 feet lower, lies about 30 rods east from the foregoing; its crest is at 1,198 to 1,195 feet, sinking a few feet from south to north; it is divided from the higher beach by a continuous depression about 3 feet deep.

Very massive beach ridge, composed of sand and gravel, with pebbles and rock fragments, the largest only slightly water-worn, up to 6 inches in diameter, passing a few degrees west of north through the center of Sec. 20, T. 159, R. 56, crest in the south half of the section, 1,208 to 1,215 feet; in the north half, 1,215 to 1,223 feet. On the east is a descent of 20 to 30 feet within 25 to 40 rods, and on the west 10 or 12 feet from the highest part of the beach within 10 rods to a nearly level area of till, 1,211 feet, which sinks 40 rods farther west to a long slough, about 1,205 feet, parallel with the beach and one-sixth of a mile wide. Beyond this an undulating surface of till, partly covered with bushes and small trees, rises to 1,250 or 1,275 feet within 2 miles, and then in smooth massive swells to 1,450 or 1,500 feet within the next 2 to 4 miles. These are

part of a plateau, thence rising more slowly westward, whose boundary for the next 50 miles or more to the north and northwest is the conspicuous escarpment called Pembina Mountain.

The north end of this massive beach bears on its crest an artificial embankment 100 feet long from east to west and 20 feet wide, raised 2 feet above the natural surface, its top being 1,225 feet above the sea. This is 10 rods south from where the beach is cut to 1,210 feet by a wide gap, as of some ancient watercourse. In the south edge of the SW. ¼ of Sec. 17, T. 159, R. 56, on the south bank of the North Branch of Park River, about 10 rods east from the ford of the "Half-breed road," this beach has an elevation of 1,220 feet.

North Branch of Park River at this ford, 10 to 15 feet wide and a few inches deep, 1,203 feet. Surface at Garder, a mile east, 1,175 to 1,170 feet. Lower Herman beach, passing from south to north along the east side of Secs. 20 and 17, T. 159, R. 56, a third of a mile west of Garder, about 1,185 feet.

FROM GARDER NORTH TO THE TONGUE RIVER.

Secs. 17, 8, and 5, T. 159, R. 56, rise from 1,190 and 1,200 feet on their east side to 1,220 and 1,225 feet on the west, including, therefore, the upper Herman shore of Lake Agassiz; but they present no considerable deposits of beach gravel and sand. A swell of till, sprinkled with very abundant bowlders, nearly all archean granite and gneiss, up to 5 feet in diameter, extends from south to north across the line between Secs. 8 and 5, having its crest at 1,215 feet, from which there is a steep descent of 10 or 12 feet to the west. Sloughs and pools of water, permanent through the year, lie in the west part of Sec. 5, about 1,190 feet above the sea.

The South Branch of Cart Creek in Secs. 31 and 32, T. 160, R. 56, is bordered by a belt of timber a half mile wide; but it has only a small channel a few feet below the general surface and is dry through the greater part of the year. Its alluvial gravel, like that of the Middle and North Branches of Park River, is mostly cretaceous shale, derived from the gorges eroded in this rock at the sources of these streams in the Pembina Mountain.

Along the western border of Lake Agassiz here and northward into Manitoba extends a prominent wooded bluff, the escarpment of a treeless plateau which from its crest stretches with slow ascent westward. This escarpment, commonly called the second Pembina mountain, is a very marked feature in the topography for at least 50 miles. It is caused by the outcrop, mostly overspread by glacial drift, of a continuous belt of nearly horizontal cretaceous shale, several hundred feet thick, usually so hard and enduring that it is popularly termed "slate." Its course coincides nearly with the west line of Ts. 159 and 160, R. 56. Thence it continues in an almost straight course, a few degrees west of *north*, through Secs. 31 and 30, T. 161, R. 56; Secs. 24, 13, 12, and 2, T.

161, R. 57; Secs. 35, 26, 22, 15, 10, 9, and 4, T. 162, R. 57; Secs. 33, 28, 21, 16, 9, and 4, T. 163, R. 57; and Secs. 33, 32, and 29, T. 164, R. 57, to the international boundary, beyond which it soon turns more to the northwest. The base of the ascent is about 1,225 feet above the sea and its crest approximately 1,500 feet, northward to the Pembina River, beyond which the base sinks to 1,150 and 1,100 feet and the crest to 1,400 and 1,300 feet. The width occupied by the slope varies from a quarter to a half of a mile.

Natural surface at the quarter-section stake on the north side of Sec. 32, T. 160, R. 56, 1,178 feet above the sea. Secs. 32, 29, and 20 of this township are mostly till, smoothed by this glacial lake, the depressions having been filled by leveling down the higher portions, where many bowlders partially embedded testify to considerable erosion. A broad ridge of beach sand and fine gravel, 3 to 5 feet high, extends from south to north through the center of Sec. 29, its crest being at 1,180 to 1,182 feet. This is the third in the series of four Herman beaches observed near Maple Lake, near Larimore, and in T. 158, R. 56. The higher beaches are probably also recognizable 1 to 1½ miles farther west, near the base of the "second mountain," which is 1,220 to 1,230 feet above the sea; but it is impracticable to trace their course and determine their exact elevation, because woods reach from the base of this escarpment a half mile east, where these beaches belong.

Fourth Herman beach, a broad low swell of sand and gravel, extending north-northwesterly through the east half of Sec. 20, T. 160, R. 56, 1,166 to 1,172 feet; through Secs. 17 and 8, an eighth to a quarter of a mile wide, 1,161 to 1,173 feet, having in some places a depth of at least 10 feet, as shown by wells. On the north line of Sec. 20 and again in the north part of Sec. 17, it is intersected by branches of Cart Creek, which occupy valleys about 40 feet deep and an eighth to a quarter of a mile wide. Brush and scattered trees grow in these valleys and on the area between them. Toward the east a descent of 30 or 40 feet is made within the first half mile; westward there is only a slight ascent, to about 1,200 feet, in 1 mile; then a more considerable slope, covered with woods, rises 20 to 40 feet to the base of the "second mountain," on or near the township line.

In the west part of Sec. 8 and again near the northeast corner of Sec. 6, T. 160, R. 56, this beach is intersected by the headstreams of Willow Creek, in valleys about 35 feet deep. On the north line of Secs. 5 and 6 of this township, the fourth and third Herman beaches are merged in an undulating tract of gravel and sand a half mile wide, which rises from 1,160 feet on the east to 1,184 feet on the west. A well on the west part of this belt found the beach deposit 6 feet thick, underlaid by till, which forms the slightly ascending surface next west.

Base of second Pembina Mountain in the east half of Sec. 31, T. 161, R. 56, 1,235 at the south to 1,220 feet northward, coinciding nearly with the upper Herman shore of Lake Agassiz. William Crombie's well, 24

feet deep, near the center of Sec. 30, situated about 50 feet above the Tongue River, a few rods back from the verge of its north bluff, was soil, 2 feet; gravel, nearly all cretaceous shale, 8 feet; underlaid by gravel, nearly all granite and gneiss, with scarcely any intermixture of shale, containing pebbles and cobbles up to 4 inches in diameter, 14 feet, yielding a permanent supply of water. This well is close to the base of the "mountain," at an elevation of about 1,230 feet. Its bed of granite gravel appears to be the upper beach, the overlying shale gravel being a delta deposit brought by Tongue River.

Surface at Young post office, in the northeast corner of the SW. ¼ of Sec. 32, T. 161, R. 56, 1,192 feet. The well here, 14 feet deep, is wholly stratified gravel and sand, being a beach deposit of the second and third stages in the Herman series. Third beach, about an eighth of a mile east of Young post office, a broad ridge of sand and fine gravel, a few feet above the land on its west side, crest, 1,187 feet. Fourth and lowest Herman beach, of similar form with the last, but larger, running a few degrees west of north through the west edge of Sec. 33, 1,173 to 1,175 feet, with depression of 1 to 5 feet on its west side and descent of 25 feet within 30 or 40 rods east. About a third of a mile east from the crest of the last is another parallel beach ridge, belonging to the Norcross stage of this glacial lake.

Tongue River at bridge near the center of the south half of Sec. 28, T. 161, R. 56, about 1,110 feet; bottomland, 10 feet higher; top of bluffs, about 1,150 feet. Gavin's Creek in the south half of Sec. 20, about 1,140 feet; valley 40 feet deep, a sixth of a mile wide.

Lowest Herman beach, a massive ridge of sand and fine gravel, in the NE. ¼ of Sec. 29 and the east part of Secs. 20 and 17, T. 161, R. 56, 1,175 to 1,180 feet.

DELTA OF THE PEMBINA RIVER.

The largest tributary to the Red River in Dakota is the Pembina River, which has cut a valley about 400 feet deep and a mile wide in the plateau of the second Pembina Mountain. During the recession of the ice sheet this stream appears to have been much larger than now, being the outlet of glacial lakes in the basins of the Souris and Assiniboine Rivers.[1] From the bend of the Souris, or Mouse River, eighteen miles southwest of its mouth, the river discharging the waters of these lakes ran southeasterly to the Pembina River. Pelican Lake, eleven miles long from northwest to southeast and about a mile wide, occupies a part of the channel of this stream; and a distinct water-course of similar width, called Lang's Valley, eroded 150 to 200 feet below the general level, extends eleven miles between this lake and the Souris River. The highest portion of Lang's Valley is 1,364 feet above

[1] Ninth Annual Report of the Geological and Natural History Survey of Minnesota, [illegible]42; and Hind's Report of the Assiniboine and Saskatchewan Exploring Expedition, [illegible] pp. 118 and 168.

the sea, and is bordered by bluffs that rise 160 feet. It is a channel similar to that of Lakes Traverse and Big Stone and Brown's Valley, eroded by the River Warren. The delta deposited in the margin of the glacial Lake Agassiz by the Pembina River, thus swollen by a great affluent from the melting ice fields beyond the present limits of its basin, extends twelve miles from south to north and has a maximum width of seven miles, with a maximum thickness exceeding two hundred feet. About five-sixths of this delta of fifty square miles or more lie south of the Pembina River, reaching nearly to the Tongue River.

Its elevation in the northwest part of Sec. 17, T. 161, R. 56, is 1,200 feet; thence northward it rises slowly in two miles to 1,225 feet in the east part of Sec. 6; and in Secs. 31 and 30, T. 162, R. 56, it varies from 1,220 to 1,227 feet. From this crest of the southern part of the delta it slopes slowly east and northeast to 1,080 and 1,090 feet at its eastern border, in Secs. 25, 24, and 13, which coincides nearly with the east line of this T. 162, R. 56. Deep valleys, with frequent tributary ravines, have been eroded in it by several small streams. Westward the delta reaches to the base of the "second mountain," the belt a half mile to one mile wide next beyond the crest, only about 5 feet lower, being a very flat, beautiful prairie, which rises slowly, like the crest, from south to north. The elevation of this belt in Sec. 18, T. 161, R. 56, is 1,190 to 1,195 feet, and at Mr. Henry Goff's house, in the middle of the east edge of Sec. 36, T. 162, R. 57, 1,221 feet. Farther west there is an ascent to about 1,240 feet at the base of the "second mountain." Wells on this area penetrate only beds of sand and gravel, easy to dig and needing to be curbed to prevent caving. A large proportion, probably half, of the gravel is cretaceous shale. Water is obtained at depths varying from twenty-five to sixty feet.

Natural surface at the northwest corner of Sec. 30, T. 162, R. 56, 1,227 feet.

The part of the Pembina delta thus far described is divided from its central and higher part by a depression about a mile wide, through which a portion or the whole of the river flowed during much of the time in which this delta was formed. In the southwest corner of Sec. 18, T. 162, R. 56, this depression is 1,205 feet above the sea, being 20 feet lower than the area on the south. It extends eastward with a slow descent and rises westward to 1,215 feet close east of the Little Pembina River in Sec. 15, T. 162, R. 57. This stream flows through the escarpment of the "second mountain" in the SE. ¼ of Sec. 22, about a mile south from this lowest part of the divide on its east side. It there turns abruptly from its eastern course and thence flows north-northwest along the base of the "second mountain" to its junction with the Pembina River; thus leaving the depression just described, which would seem to be its more natural course, and taking in its stead a channel that is eroded through a portion of the delta 50 feet higher.

The most elevated point of this delta, as it now remains, is about 1,270 feet above the sea, near the northwest corner of Sec. 11, T. 162, R. 57, east of the Little Pembina and south of the Pembina River, nearly 300 feet above the junction of these streams, 1½ miles distant toward the northwest. Sec. 12 of this township and the west part of Sec. 7, T. 162, R. 56, slope from 1,225 on the south to 1,215 feet on the north; their southern part is the highest land crossed between the depression before mentioned and the Pembina River by the line dividing these townships. The level of Lake Agassiz in its highest stage here was 1,220 or 1,225 feet above the sea, being 50 feet below the top of the Pembina delta, as is shown by the beach line of this level, 1,226 feet, in the central part of this Sec. 7, where an eastward descent begins. This is the east verge of the nearly flat area of the delta in Secs. 12 and 7. Like all of this vast delta deposit, the material here is sand and gravel, covered by a fertile soil. A small proportion of the pebbles of this gravel is limestone; a large part is cretaceous shale; but more was derived from archean formations of granite and gneiss.

Second Herman beach, a ridge of the usual form, crossed by the road near the east side of the NE. ¼ of Sec. 7, T. 162, R. 56, descending from 1,212 feet to about 1,200 feet in a distance of a third or half of a mile from south to north.

William Roadhouse's well, 110 feet deep, in the NW. ¼ of Sec. 9, T. 162, R. 56, at elevation of 1,184 feet, is all stratified sand and gravel, with pebbles up to 6 inches in diameter, fully half cretaceous shale. Water comes in coarse sand at the bottom, filling the lowest 2 feet. Another well of the same description, but 137 feet deep, is a mile farther east, at Wellington Stewart's house, in the SW. ¼ of Sec. 4, 1,192 feet above the sea.

Crest of the first Pembina mountain in the north part of Sec. 33, T. 163, R. 56, nearly two miles southeast from Walhalla, a few rods west from the summit on the Olga road and 5 feet higher, 1,196 feet. This is a beach accumulation, belonging to the third Herman stage. On the west and southwest the undulating delta plateau, mostly covered with bushes and occasional trees, is 10 to 30 feet lower for a width of 1 to 1½ miles, averaging about 1,175 feet.

Northeast from the crest of the Olga road a short descent is made to a prairie terrace 30 to 60 rods wide, varying in elevation from 1,182 to 1,169 feet, but mainly within 2 feet above or below 1,175. In general the verge of this terrace is its lowest portion. Thence a very steep descent of 169 feet is made on the road from 1,173 to 1,004 feet, this being the very conspicuous wooded escarpment called the "first mountain." It is the eroded front of the great Pembina delta, the eastern part of which, originally descending more moderately, has been swept away by the waves and shore currents of the ancient lake during its Norcross, Campbell, and McCauleyville stages. From the north part of

this Sec. 33 the "first mountain" extends southeast to Secs. 13 and 24, T. 162, R. 56, before mentioned, and northwest across the Pembina River, passing close southwest of Walhalla and onward to Secs. 10 and 3, T. 163, R. 57. Its highest part is intersected by the Pembina River, above which it rises on each side in bluffs of gravel and sand 200 to 250 feet high, with their crests a half mile to 1 mile apart.[1]

Surface at Bellevue Hotel, Walhalla, 994 feet above the sea; at the post office, Mr. G. D. Loring's store, 968 feet; Pembina River, at the bridge, a third of a mile east of Walhalla, 934 feet.

Highest part of the Pembina delta north of Pembina River, in Secs. 25 and 26, T. 163, R. 57, 1,210 to 1,230 feet, rising slowly from east to west; in the west half of Sec. 26 and the east edge of Sec. 27, it is depressed to 1,225 and 1,220 feet; but beyond this it rises to 1,235 and 1,240 feet, next to the foot of the "second mountain." From this upper portion the delta slopes down gradually toward the northeast and north, extending only 2 to 4 miles beyond the Pembina River.

Natural surface at the quarter-section stake on the north side of Sec. 26, T. 163, R. 57, 1,191 feet.

Third Herman beach, crest 5 rods south of this stake, 1,197 feet, from which there is a descent in 5 rods south to 1,192 feet and in 15 rods north to 1,180 feet. This beach curves thence to the northwest and north, and in the opposite direction runs east-southeast 2 miles to near the center of Sec. 30, T. 163, R. 56, where its elevation is approximately 1,192 feet. Other shore lines of the Herman group were not noticed north of the Pembina River.

In the gravel of this delta, as seen in the bluffs of Pembina River near Walhalla and at noteworthy springs 2 miles to the south, on the south side of the river in the southwest corner of Sec. 32, the pebbles of some beds are mainly cretaceous shale, of others mostly limestone, and of others granite, gneiss, and dark trappean rocks. In the aggregate, these three classes have a nearly equal representation. White quartz and moss agate are frequent and bits of silicified wood occur rarely; but no banded agates were found. Numerous pieces of

[1] The first Pembina mountain was visited by D. D. Owen in 1848. He describes it as follows: "Pembina Mountain is, in fact, no mountain at all, nor yet a hill. It is a terrace of table land, the ancient shore of a great body of water that once filled the whole of the Red River Valley. On its summit it is quite level and extends so for about five miles westward to another terrace, the summit of which I was told is level with the great buffalo plains that stretch away towards the Missouri, the hunting grounds of the Sioux and the half-breed population of Red River."—Report of a Geological Survey of Wisconsin, Iowa, and Minnesota, 1852, p. 178.

Both the first and second Pembina mountains were examined in 1857 by Palliser, who says of the flat Red River Valley and the Pembina delta: "This plain, no doubt, had formed at one time the bed of a sheet of water, and the Pembina Hill, consisting of previously deposited materials, was its western shore."—Journals, detailed reports, &c., presented to Parliament, 19th May, 1863, p. 41.

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Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V. Volume VI is not yet complete.

The following are in press, viz:

41. Fossil Faunas of the Upper Devonian—the Genesee Section, by Henry S. Williams.

42. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1885-'86. F. W. Clarke, chief chemist.

43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In preparation:

— Historic statement respecting geologic work in Texas, by R. T. Hill.

— The Nature and Origin of Deposits of Phosphates of Lime, by R. A. F. Penrose, jr.

— Bibliography of North American Crustacea, by A. W. Vogdes.

— The Gabbros and associated rocks in Delaware, by F. D. Chester.

— Report on Louisiana and Texas, by Lawrence C. Johnson.

— Bibliography of North American Geology for 1886, by Nelson H. Darton.

— On the subaërial decay of rocks and the origin of the red color of certain formations, by Israel C. Russell.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

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UNITED STATES GEOLOGICAL SURVEY

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ILLUSTRATIONS.

CHANGES IN RIVER COURSES IN WASHINGTON TERRITORY DUE TO GLACIATION.

BY BAILEY WILLIS.

Drainage lines in Eastern Washington Territory are broadly characterized by an aspect of youth, but they are divisible, according to age, into preglacial and postglacial channels. The general slope of the region presented in Plate I is southward; such streams as the Wenatchie, Methow, Okinakane, and San Puel strike the eye as members of a possibly consequent and unmodified system, determined by processes of subaërial erosion only. Of these, the last named alone enters the area of the volcanic flow of the Columbia River plain; the other valleys are carved upon the older surface of granite and crystalline sedimentary rocks. These valleys are also broader and more advanced in their development than the cañon of the Columbia, which crosses their direction nearly at right angles, and, cutting through the northern corner of the great flow from the Spokane River to the Okinakane, meanders along the contact of the basalt with the granite thence to the Wenatchie. The sudden northwestward turn of the river at the Spokane and its relation to the western limits of the eruptive rocks suggest that its course was determined by southward and by northward and westward volcanic flows, as indicated by arrows on Plate I, the line of least elevation of the cooled surface having lain near the edge, i. e., at the contacts of different coulées and of the earlier rocks with them.

If this be true, an older Columbia Valley lies beneath the great plain, and the converging lines of its watershed should be elsewhere apparent outside the area of the flow. Such channels are found traversing the Cabinet Mountains, but they are no longer occupied by the greater rivers. The Clark's Fork, below Lake Pend d'Oreille, the Columbia, from Kettle Falls to the Spokane, flow through clean cut, rock bottomed cañons, parallel with valleys of equal depth, gentler declivity, and wider expansion, such as those of Colville, Vermilion, and Pack Rivers. The suggestion lies close at hand that the latter belonged to the older system and are sections of valleys now overflowed by basalt in their lower courses. Their abandonment by the great rivers is the result of the much later causes of the glacial period, when valleys were filled with

drift and rivers were driven to seek new channels across the lowest gap in their watersheds.

Through the kindness of Prof. T. C. Chamberlin I am able to give here the unpublished results of his observations of the glaciation of the region about Lake Pend d'Oreille.

The rugged crest of the Cabinet Mountains northeast and northwest of the lake is traversed by a depression a mile wide, known as the Pack River or Kootenay Pass. Gentle slopes descend northward to Bonney's Ferry and southward to the lake; the broad valley of the Kootenay extends far into British Columbia on the one hand and the level gravel plains of the Spokane spread in the opposite direction.

The Kootenay enters upon its placid northward flow from a cañon 50 miles long, one of the deepest and most abruptly walled of the Northwest; the Clark's Fork also descends to Lake Pend d'Oreille by a cañon and leaves it to traverse another, so wild that no one has passed through it. Of these channels, that of the ancient river, which flowed northward or southward through Pack River Pass, is certainly very much the oldest. During the ice age it was occupied by a glacier, which, descending from the north, filled the basin of Lake Pend d'Oreille and spread its moraine before the valleys on either hand. The lakelets that lie along the base of the Rocky Mountains are the products of its morainal dams, and from it sprang the great gravel stream of the Spokane and the Cœur d'Alene plains. Roches moutonnées and glacial striæ are abundant in Pack River Pass and about Lake Pend d'Oreille, but they are wanting on the surfaces of volcanic rocks about Spokane Falls, and there is no evidence that the ice reached so far.

Professor Chamberlin was not equipped for trips into less accessible districts; the western limits of this glacier are therefore undetermined, but the facts observed by him in the vicinity of Lake Pend d'Oreille are paralleled elsewhere in Northern Washington Territory, and similar topographic conditions suggest analogous causes.

The first instance of this kind is found in the open valley of the Columbia, above Kettle Falls, and its southward continuation in the valley of Colville River and Chamokane Creek, which contrasts with the cañon now followed by the Columbia below Kettle Falls. This wider valley is now occupied by these two small streams, of insufficient volume or fall to remove the gravel over which they flow, and much less able to cut the channel which should carry a great river. They are separated only by a divide of gravel, terraced by erosion, and do not touch bedrock throughout their courses. The Colville River flows through marshes; Chamokane Creek has a swifter current, but is much smaller. It is apparent that a large river once flowed south or north through this channel and that of the Columbia above Kettle Falls, and it may be inferred that the valley was occupied by a glacier, as was that of the Kootenay, and that with the retreat of the ice the postglacial Columbia

River was forced by a drift dam across a low divide into its present course. On Plate I are given the elevations bearing on this problem, as determined barometrically by Mr. Louis Nell, then of the Northern Transcontinental Survey, in mapping the area east of the Columbia and north of the Spokane River.

Another north and south depression of preglacial age is now occupied by Curlew Creek, which is said to rise in a rolling gravel plain, and which flows northward to Kettle River. The elevation of the divide at its head was found by United States engineer officers of the Department of the Columbia to be about 2,500 feet; that of its mouth is about 1,700 feet, as determined by aneroid, compared with Spokane Falls. This broad, gently sloping valley is gravel floored, and the older stream had cut a deeper channel than the present one. Curlew Creek flows over but a short section of the older valley, but there is little known evidence to trace the latter in either direction. The course of Kettle River toward it is down a precipitous cañon, which is more open below its northeastward turn. Analogy with other great valleys of the region would suggest that the Upper Kettle River was but a tributary of the former stream, which flowed southward to and under the locus of Curlew Creek.

Still another deep channel, now drift filled and abandoned to small sluggish streams, extends from Miner's Bend, on the Similkameen River, southward (Plates II and III). It presents three sections, two of which terminate with open passes, leading eastward to the Okinakane. The northern division, from Miner's Bend to Wagon Road pass, is a comparatively broad valley, a strip of marsh and lake between steep mountain slopes. The terraces on its sides are continuous with others, which cling to the walls of the Similkameen Cañon below Miner's Bend, and they extend southward to the Three Pools, where they merge into the highest portion of the drift filling.

The second section, that between Wagon Road pass and Fish Lake, is a drift clogged cañon, with abrupt granite walls of considerable height; its northern half presents a very gentle northward slope. From the Three Pools southward the drift surface is dotted with kettle-holes. Terraces again appear on the slope of the mountain northeast of Fish Lake and close the entrance of the pass, which trends eastward. The waters of Fish Lake are held by a gravel dam, from beneath which a small stream escapes into the very narrow and crooked upper channel of the southern portion. The descent from Fish Lake is very rapid and is strewn with bowlders of large size. After passing a very deep and narrow pool three-fourths of a mile long, into which the brook sinks, the valley opens out between limestone bluffs and drift terraces, and ends abruptly in a cul de sac at the head of Johnson Creek (Plate III), the further continuation, whether southwestward or southeastward, being now completely filled.

There can be no question that the cañon described is an old subaërial channel, very probably traversed by the Similkameen. One possible interpretation of the facts is that a glacier descended the valley and discharged through the several low passes eastward. In the several stages of its existence and retreat it spread the drift which now terraces the cul de sac, deposited the coarse material of a temporary terminal moraine below Fish Lake, produced the broad gaps in the hills on the east by glacial and subaërial erosion, and in its later stages left the gorge so dammed that the Similkameen found its present direct and rapid descent to the Okinakane River.

The valley of the latter belonged no doubt to the great system of which all these now abandoned channels were part. Like them, it was drift buried, but, unlike them, not dammed, because of its great width. The present river is a quiet stream, having a fall of about 3 feet per mile from Lake Osoyoos to the Columbia River, and usually flowing between terraces 400 feet high. The lake is but a shallow expansion of the river, retained by a drift deposit.

Other evidences of glaciation are found on that part of the Columbia sketched on Plate IV. A broad gravel plateau, the analogue of the terraces along the Okinakane, lies between the right banks of the Columbia and the Methow River, and is continued down the former wherever the cañon walls are not too abrupt.

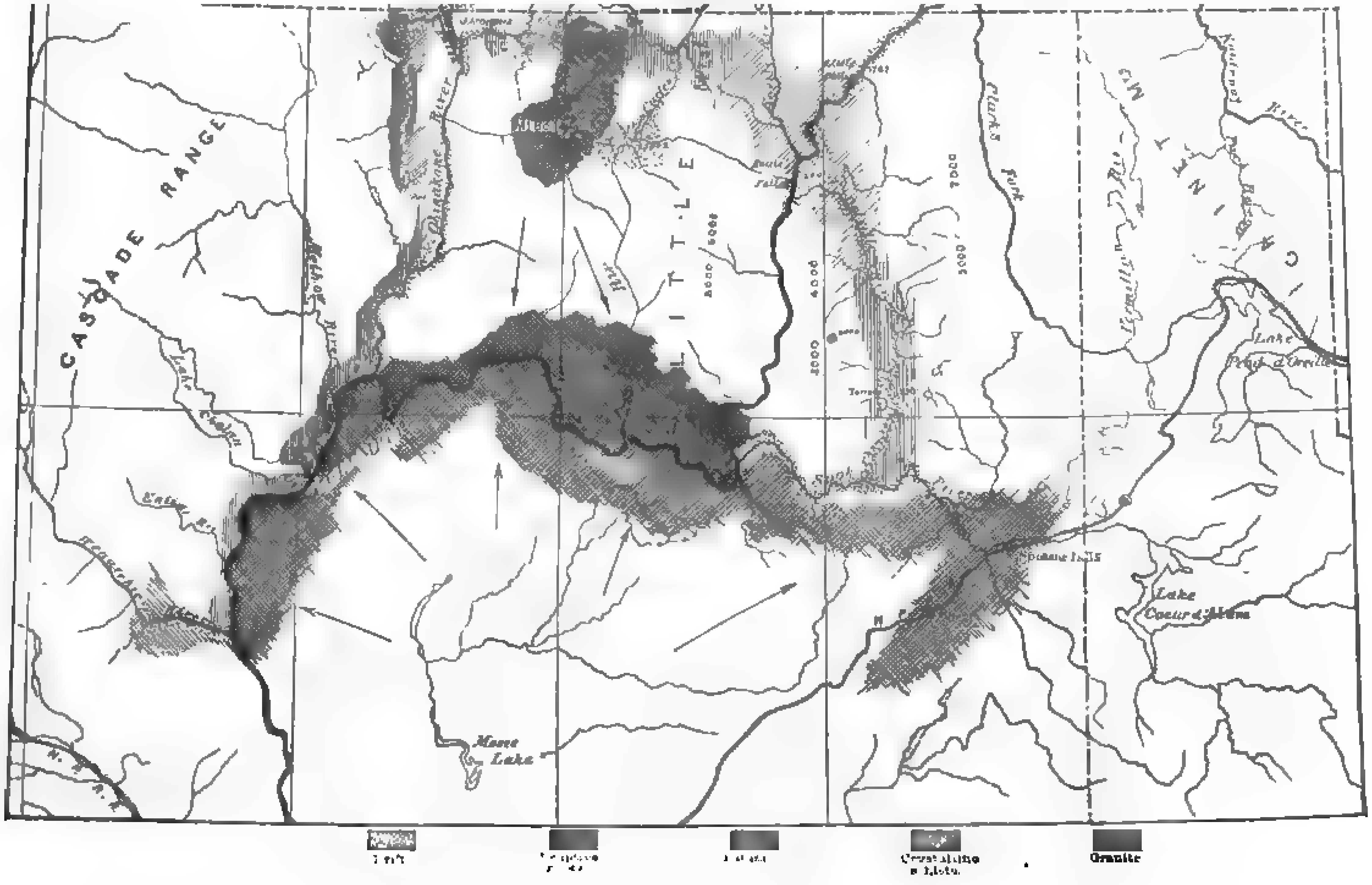
An older channel of the Columbia is traversed by the trail just above Lake Chelan, and the bed of the latter was probably deepened by the glacier, which rounded the outcrops about its shores and left the coarse morainal material of a small lateral discharge in the cañon by which the trail leaves the lake basin on the south.

The preceding observations show the former existence of glaciers in the river valleys of the extreme northern part of the Territory, either as portions of a general ice sheet or as tongues pushed forward from disconnected ice rivers descending from the north. It is in keeping with either hypothesis that roches moutonnées should occur, as they do on the mountains south of the forty-ninth parallel, produced on the one hand by the great ice mass or on the other by streams radiating from local centers.

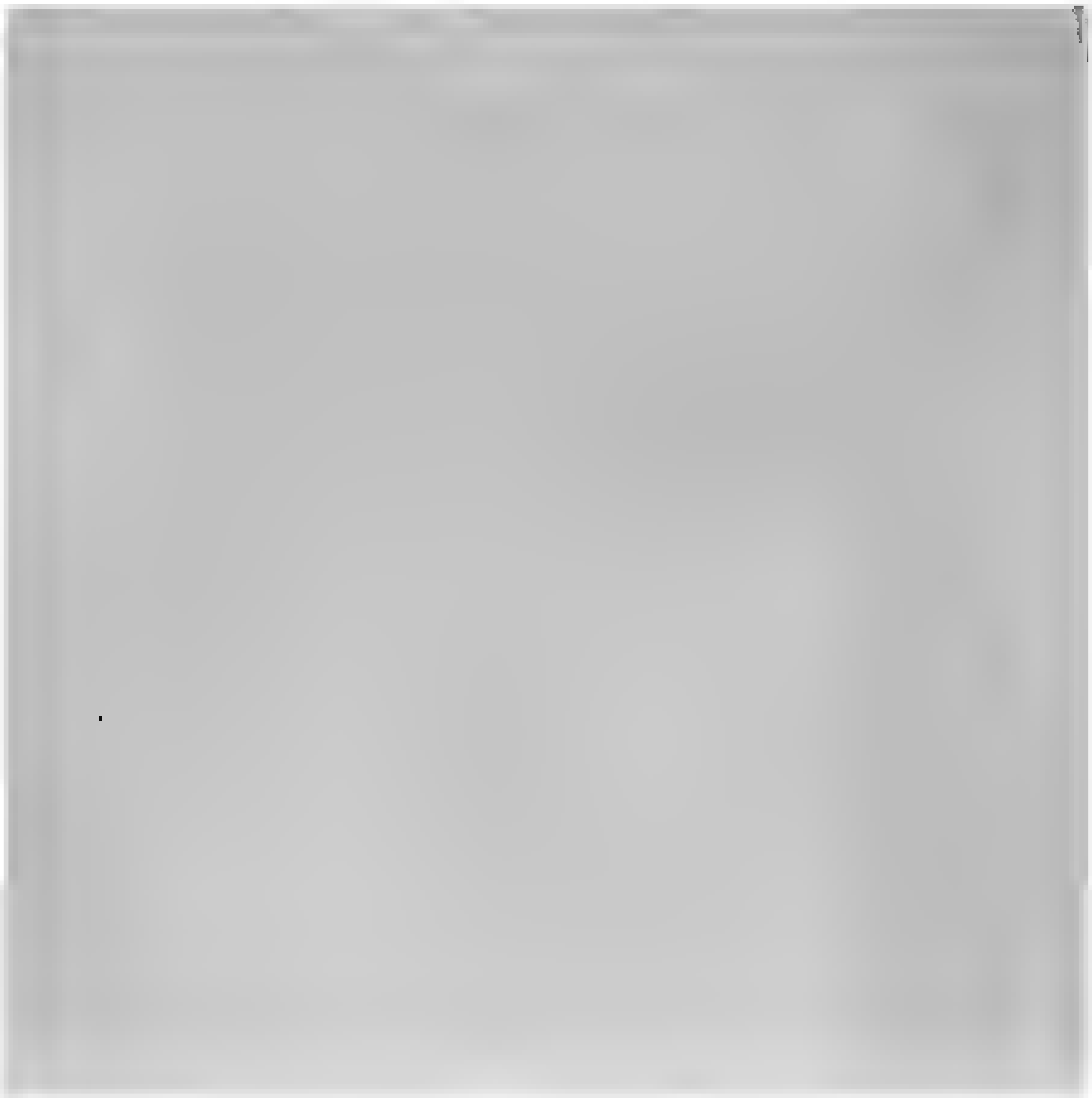
The extent and the direction of flow of the glacier or glaciers therefore remain open questions, to be studied with that detail which the interesting phenomena of the region invite.

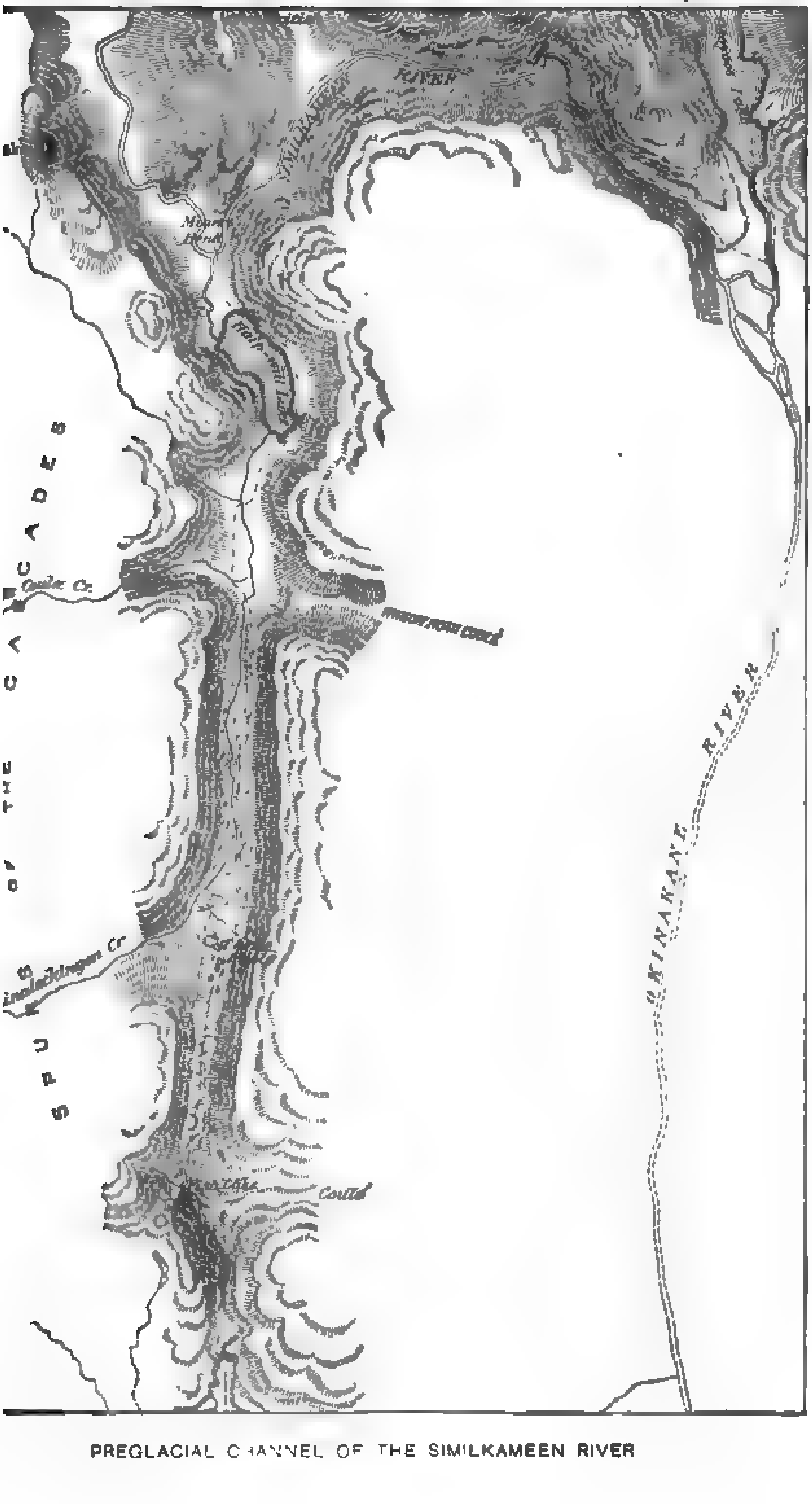
The reconnaissance work upon which these notes are based included observations of distribution of rock groups, the results of which are given on Plate I.

No determinations of age were possible, as no fossils were found, and the classification adopted is consequently of a broad lithologic character.

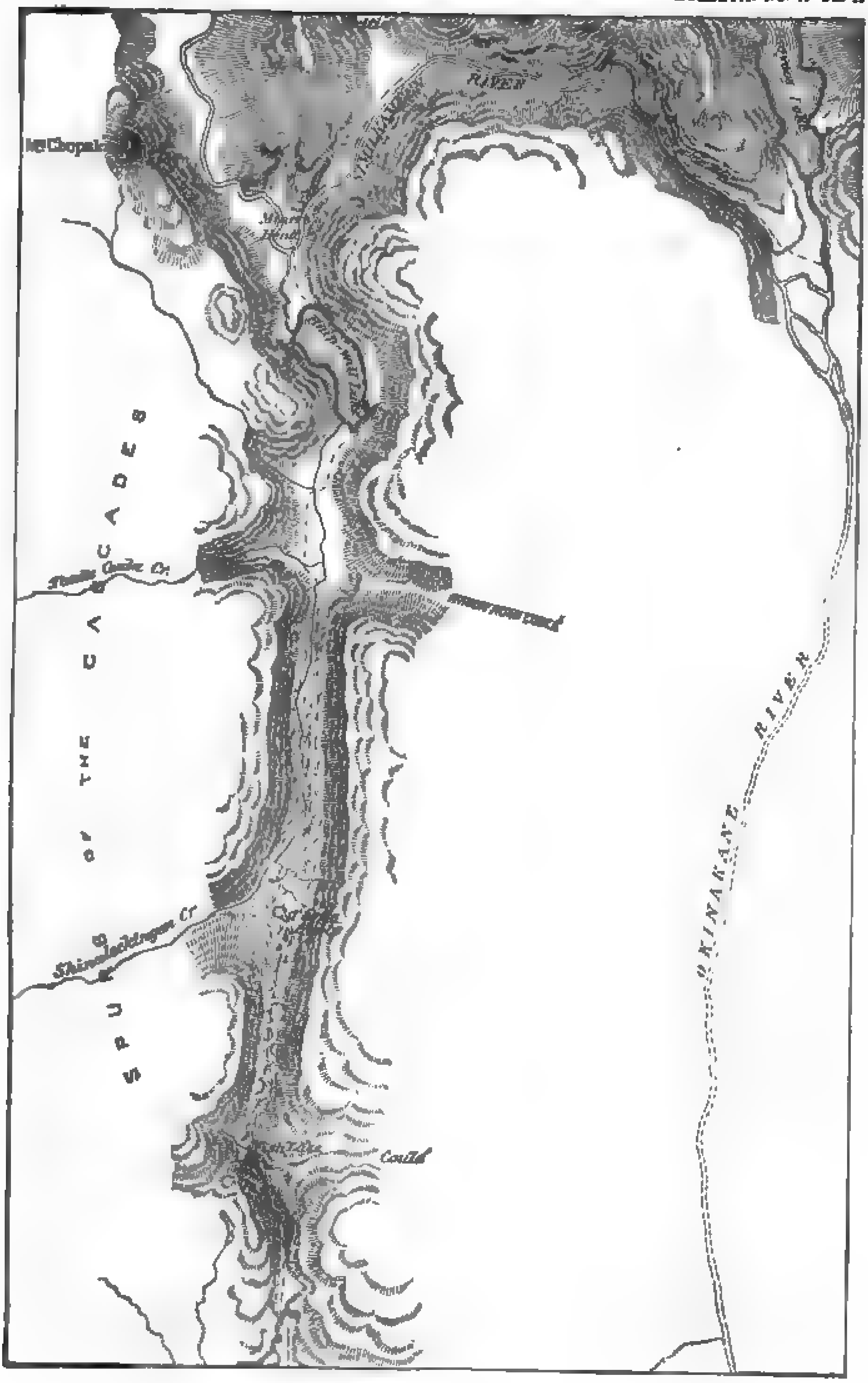


CASCADE RANGE
LITTLE
CABINET MTS
Lake Chelan
Moses Lake
Lake Coeur d'Alene
Lake Pend d'Oreille
Okanakane River
Clark's Fork
Spokane Falls
Crystalline schists
Granite





PREGLACIAL CHANNEL OF THE SIMILKAMEEN RIVER



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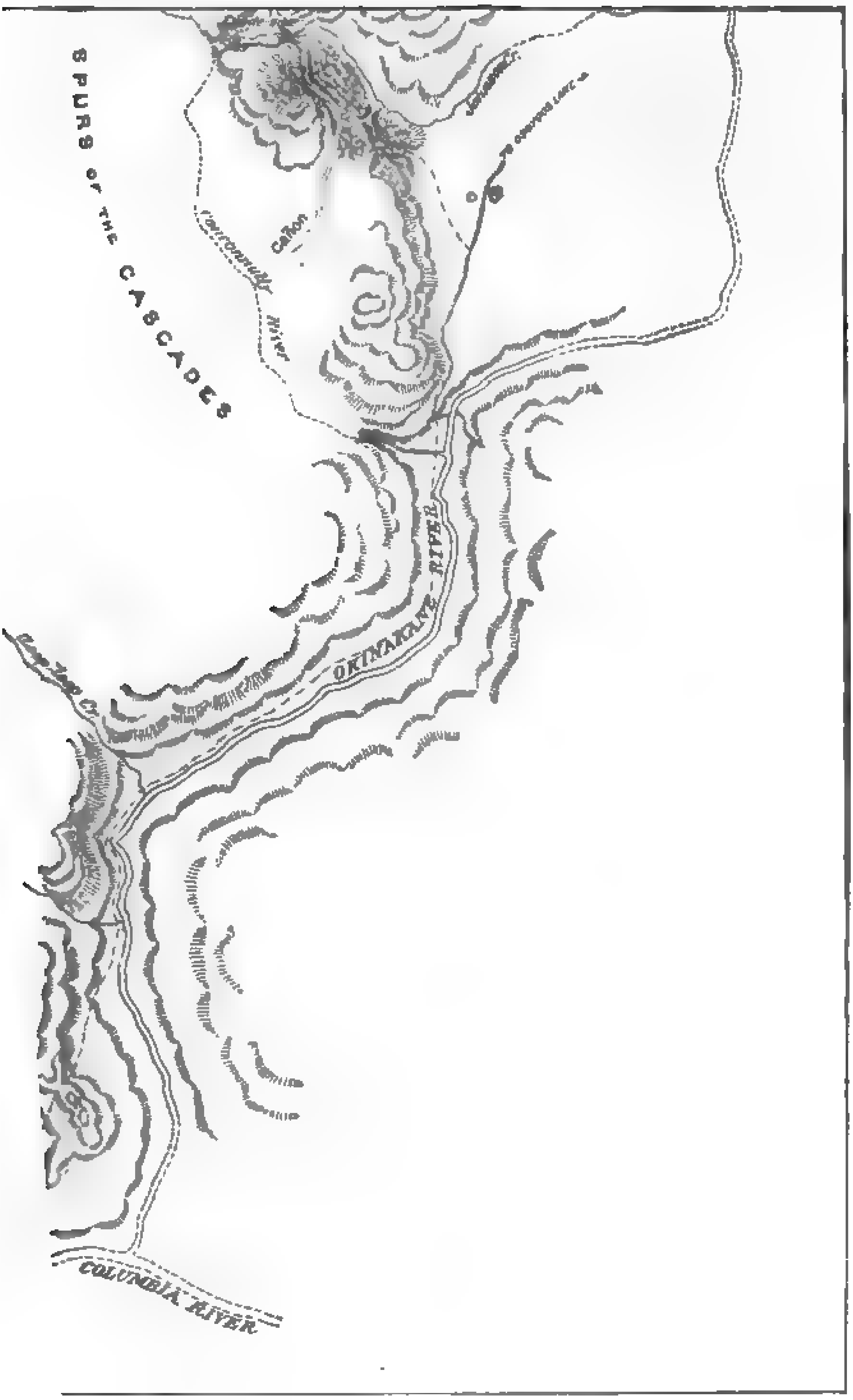
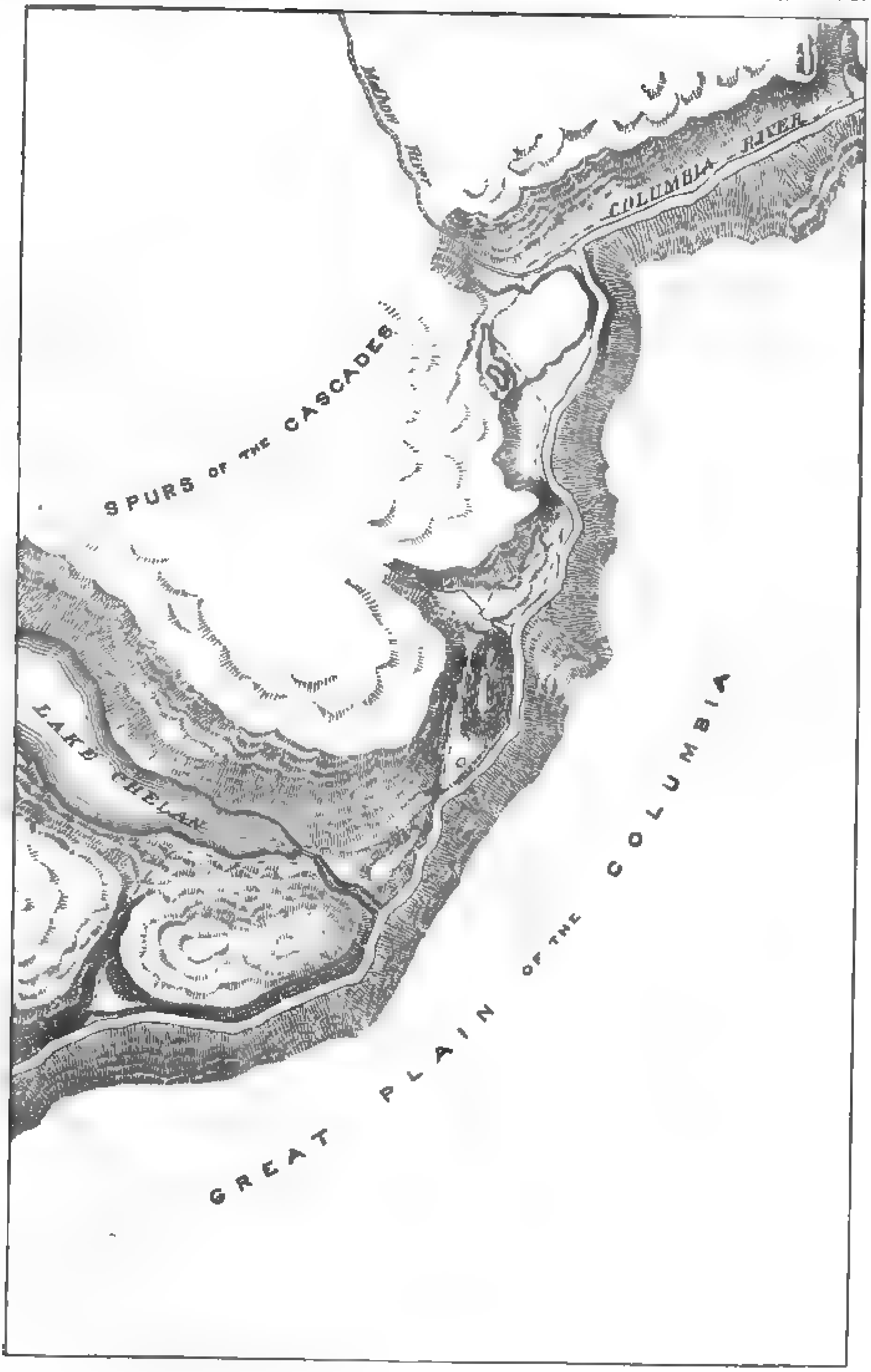


LOWER VALLEY OF THE OKINAKANE RIVER TO THE COLUMBIA RIVER.



COLUMBIA RIVER FROM OKINAKANE RIVER TO LAKE CHELAN

NOTICE.

The bulletins of the United States Geological Survey are numbered in a continuous series and will be bound in volumes of convenient size.

This bulletin will be included in Volume VI.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 41

ON THE FOSSIL FAUNAS OF THE UPPER DEVONIAN—THE GENESEE SECTION, NEW YORK.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

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— Report on the Geology of Louisiana and Texas, by Lawrence C. Johnson.
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— Fossil Woods and Lignites of the Potomac Formation, by F. H. Knowlton.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published.

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

In press:

— Mineral Resources of the United States, 1886, by David T. Day. 1887. 8°.

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To the Director of the
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Washington, D. C.

Washington, D. C., *November* 30, 1887.

[redacted]

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UNITED STATES

GEOLOGICAL SURVEY

No. 41

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

ON

THE FOSSIL FAUNAS

OF THE

UPPER DEVONIAN

THE GENESEE SECTION, NEW YORK

BY

HENRY S. WILLIAMS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
ITHACA, N. Y., *August* 2, 1886.

SIR: I have the honor to transmit herewith for publication as a bulletin a second contribution to the study of Devonian paleontology, Bulletin No. 3, "On the Fossil Faunas of the Upper Devonian," having been designed as the first of a series of papers on the comparative paleontology of the Devonian and Carboniferous.

In that paper I gave the results of a study of the section along the meridian of Ithaca and Cayuga Lake, running southward, which may be called the Cayuga section.

In 1883 examination was made south along the meridian running through Genesee County, New York, into McKean County, Pennsylvania, where the Alton coal beds were reached. The general results of this survey were communicated to the Director of the United States Geological Survey and an abstract of my communication was published in Science, Vol. II, pp. 836, 837, December 28, 1883. The present paper is a detailed report of the study of the materials of this Genesee section.

Since the field work was done several additional sections have been examined: in 1884, sections through Western New York (and adjoining Pennsylvania) from Chautauqua County westward and into Ohio as far as the meridian of Cleveland; and in 1885 the region between the Cayuga section and those of Delaware and Otsego Counties, as far as Oneonta, were examined. The materials are under investigation and will be reported upon as soon as their study is completed.

The sections are made along meridians, in order to make them more readily and simply comparable. Each long meridional section runs through the same stratigraphical series of deposits and is made up of a series of small local sections, such as the individual outcrop of the rocks renders possible.

It is not supposed that in any case these sections are exhaustive, but it is intended that so far as they go the relative position of the faunas in the sections shall be precise and the association of species in each horizon shall be given as it is, so that the faunas can be identified, and thus, while they will leave much to be added, these studies, it is hoped, will give an outline of the geographical distribution and geological range of

faunas and their species which will make a comparative study of the faunas possible.

In the arrangement of the material of this report I have followed simply the order in which the various sections were originally made, which is in general from north to south and from below upward. The numbering of the stations is that which the specimens will receive when finally deposited in the National Museum. The system used in marking the sections and the specimens representing them is as follows: A number is assigned to each principal locality, as 468 Attica, 477 Cuba, 487 Olean, &c. A letter is assigned to each section, as 477 A, Armstrong quarry, Cuba; 477 C, Smith quarry; 477 E, a ravine south of Cuba. For each section the individual strata or fossiliferous zones receive numbers, running from below upward wherever this order was practicable; thus 477 E^2 is the principal brachiopod zone of this particular ravine, 477 E^5 the red band of the same section.

In the present report special discussion of the faunas of the Hamilton group and of those below the black shales of the Genesee group is omitted, since the sections along this meridian do not present the series with sufficient fullness to throw any new light upon their history. The facts gathered will be presented in their connection when a more typical series of this part of the Devonian is prepared for comparison.

Respectfully yours,

HENRY S. WILLIAMS.

Maj. J. W. POWELL,

Director U. S. Geological Survey.

UPPER DEVONIAN FOSSIL FAUNAS—GENESEE SECTION.

By Henry S. Williams.

INTRODUCTION.

The description of fossils is a most important work for the paleontologist, but it is believed that a still more interesting and a wider field is awaiting his investigation in the comparative and historical study of organisms. This field is open for all who will undertake it, and, while the professional paleontologist may be able to map out the grander features and problems, very much must be left for the local student to fill in by careful and thorough search in his own region. This same line of investigation should be followed out in all the geological stages, and each student will find his best field in that region in which he can make most diligent search. In the present case the selection of the Devonian was determined by the simple fact that the Devonian rocks were for the writer the most accessible. These outcrops are near at hand and therefore can be thoroughly studied. The Silurian offers like opportunities for those residing in the midst of Silurian rocks, the Mesozoic for others.

Scarcely ever do good species range through more than a single geological system, and hence a scrutiny of the laws of the modification of species may be best effected by confining our comparisons to the species of a single system. Till we gather some definite knowledge as to the laws of modification which species undergo when traced through varying geographical conditions and in their geological range, our ideas in regard to modification of genera and families must necessarily be hypothetical. It is hoped, too, that these investigations may throw some light upon the nature of what we call species—as to what may be the conditions determining the constancy of certain characters and the plasticity of others. In order to do this, data must be collected showing what the constant and what the plastic characters actually are, and this in regard to particular species, at particular stages, and in particular regions.

In a paper read at the Ann Arbor meeting of the American Association for the Advancement of Science, 1885, I communicated some of the general results of comparison of the several faunas of the Upper Devonian,

as seen in the various sections from Oneonta, Otsego County, N. Y., westward to Cleveland, Ohio. I then named the several long sections whose faunas were made the subjects of comparison. The section described in the present paper is there called the Genesee section. In reference to the identification of species in this paper, I wish particularly to state that I regard them in many cases as imperfect and provisional.

The careful comparison of large series of specimens from the same and from different localities and from different zones has brought out so conspicuously the variability in many of the characters used in the definition of species that the limitation and the validity of species are often called in question. But in order to speak of them and to discuss the problems involved it is necessary to use some names. The rule I have adopted, therefore, is to apply to specimens which have come from the same localities and horizons the names which are in common use in the reports and in the museums where the typical specimens may be found named and described. The literature, too, is often confused, and forms which ought to go under a single name are often called by different names by different authors. This is particularly noticeable when comparisons of our material are made with collections from Europe or from distant portions of our own land. Further, there are in common use in our American literature generic names of very doubtful value, which may be dispensed with to the advantage of science. But to adjust these errors would involve technical and detailed discussion, not appropriate to this paper, and I have therefore somewhat sacrificed precision in the use of nomenclature in order to bring out more clearly, for those familiar with the State reports and the museums in which the typical collections are contained, the general characters of the faunas.

As preparation for these investigations I owe much to the abundant and instructive labors of geologists and paleontologists who before me have studied deeply into the problems and done much toward their solution. In this country, Messrs. James Hall, J. S. Newberry, A. Winchell, C. A. White, and later Messrs. John F. Carll, I. C. White, C. A. Ashburner, and H. M. Chance, in connection with Prof. J. P. Lesley, of the Pennsylvania survey, and Mr. Edward Orton, the present State geologist of Ohio, Messrs. F. B. Meek and A. H. Worthen, of the Illinois survey, and Mr. Carl Röminger, of the Michigan survey, and others, in a more general way, have taken more or less active part in elaborating the facts and in determining the relations which the complicated series of deposits sustain toward one another. In Great Britain the discussion which centered about the Devonian problem, the relation of the Devonian marine deposits and the Old Red Sandstone, is full of instruction, beginning with the classic paper of Murchison and Sedgwick, and expressed most forcibly in the papers of Murchison, Salter, Jukes, Hall, and Champernowne, and practically settled for Great Britain in the exhaustive paleontological paper of Sir Robert Etheridge

in 1867. Most of these articles may be consulted in the Transactions and Journal of the Geological Society of London. Recent investigations on the Devonian series of Northern France and Belgium have thrown light on the general problem. The papers of MM. Gosselet, Barrois, and Mourlon may be specially mentioned. Valuable suggestions are also found in the papers of M. Emanuel Kayser on the Rhenish Devonian.

All these investigations tend to show, first: that the series of deposits which immediately preceded the Carboniferous formation, or those deposits which are of a semiterrestrial origin, at the close of the Paleozoic exhibit great variation in the nature and order of the deposits when traced over any considerable geographical area. The termination of the Devonian age and deposits underlying the true Carboniferous age have been a constant source of bewilderment to all geologists in this country who have looked outside their own immediate neighborhood. Secondly, when studied minutely, there appear to be evidences to show that the differences in the faunas in these deposits are not always chronological differences, but must be regarded often as geographical in faunas living at the same time under different conditions.

From the fact of these differences and irregularities in the deposits and in their contained faunas, they seemed to offer a particularly attractive field for studying the effects of changing conditions upon the organisms and a promising field from which to learn the laws of change which, under like conditions, might be traceable to chronological sequence, and at a common horizon could be more properly referred to geographical change of the environing conditions of life.

CHAPTER I.

REVIEW OF OPINIONS; THE BEARINGS OF THESE INVESTIGATIONS UPON THE CLASSIFICATION OF THE UPPER DEVONIAN ROCKS AND FAUNAS.

In planning these investigations into the history of organisms, the Devonian age was chosen as a particularly important field because of the numerous disputed questions there awaiting solution and because it offers, in the various exposures in this country, abundant data for investigation. Between the limits of the Corniferous limestone below and the coal deposits above is found a great thickness of strata in New York, Pennsylvania, and adjacent territory broken up into several well marked geological formations. In other parts of the United States the same series is represented by deposits containing like fossils but not always identical, nor are successive strata always composed of the same materials or arranged in the same groups as we pass out of this eastern area.

When these investigations were begun the chief question in mind was the solution of the complex problem of the equivalency of the various sections covering Upper Devonian and Lower Carboniferous horizons in various parts of the country. The first general section therefore did not extend below the Black Genesee shale terminating the Hamilton formation. The faunas from this point to the first coal, as seen along the meridian from Cayuga Lake southward, were reported upon in the United States Geological Survey Bulletin No. 3. But the problems involved are too far reaching to be limited by so indefinite a mass as the black shales lying in the Middle Devonian of New York. Although this section through the middle tier of counties in Western New York is an admirable one for the study of the Upper Devonian, it will be necessary to go farther east to find the lower faunas (i. e., above the Corniferous limestone) so exhibited as to determine the details of their history.

On entering upon fields of which the geological structure is well known and whose fossil species are generally familiar and described, I neither undervalue the excellent work of my predecessors nor expect to do anything to take the place of the geological reports already published. On the other hand, the work here attempted could not be undertaken without this preliminary mapping out of the field and working up of the species concerned.

I am here interested not in adding to the long list of described species, nor in determining to what geological period the species be-

long, but in ascertaining the laws of association, of sequence, of modification, and of distribution of species in the past. The better known and the more frequent the occurrence of the species the more satisfactory will be the results to be reached by their study. In the course of the investigations already a few new species have appeared, but much more frequently forms have been met with which lie intermediate between the typical forms of already described species.

Facts are thus accumulated for a revision of the characters essential to the distinction of species. Not only am I indebted to the work of other geologists for facts accumulated, but suggestions and partial explanations of the facts, so far as the evidence existed, have been used as guides in extending the research. I have availed myself, too, of the differences of opinion among accepted authorities as a guide to the questions needing most careful study.

On examining the series of deposits found in each State, it was of first importance to consult the published reports of geological surveys already made. I have, therefore, consulted the numerous series of reports of the State surveys of New York, Ohio, Pennsylvania, Michigan, Iowa, Missouri, Illinois, and of other States in which representative deposits were exposed.

PROF. JAMES HALL'S VIEWS.

In the volume on the Devonian Brachiopoda, 1867 (Geol. Surv. of N. Y., Pal., Vol. IV, Pt. I), Prof. James Hall recognized the increase of Carboniferous types among the species of the Upper Devonian on passing from the eastern to the western deposits of New York State; this he regarded as a mark not of a higher geological stage, but of a change in geographical conditions. He wrote (p. 257): "And finally, we have every reason to believe that in those sedimentary formations between the Hamilton group and the Coal Measures in the east, and between the same groups and the Burlington (Carboniferous) limestone in the west, the Devonian aspect of the fauna on the one hand and its Carboniferous aspect on the other are due to geographical and physical conditions, and not to difference in age or chronological sequence of the beds containing the fossils."

The mingling of Devonian and Carboniferous types in rocks of the Lake Superior region occurred to Professor Hall still earlier (see Rep. Geol. Lake Superior Land District, Foster & Whitney, 1851, p. 313), leading to the belief that the transitions are gradual and not clearly defined.

This idea, whether originating with Professor Hall or not, was never elaborated by him in public, so far as I can ascertain. In Great Britain, however, the discussion of the relations existing between the Devonian and the Old Red Sandstone, which practically terminated in Sir Robert Etheridge's masterly paper on "The physical structure of West Som-

erset and North Devon" in 1867 (Quar. Jour. Geol. Soc., London, Vol. XXIII), has brought out clearly the fact that the Old Red Sandstones, wanting in marine invertebrate faunas and filling the gap between the marine deposits of the Silurian and those of the Carboniferous, are the equivalents of the marine deposits called Devonian—not above nor below them, but contemporaneous, though in separate geographical areas.

The change in the character of the American deposits in passing westward and the differences observed in the faunas were explained by Professor Hall as due to mingling of the Devonian and Carboniferous faunas toward the west.

PROF. A. WINCHELL'S VIEWS.

In 1870 Prof. A. Winchell, in a paper (in Proc. Am. Phil. Soc., Vol. XI, pp. 57–82, 385–418) "On the geological age and equivalents of the Marshall group," objected to this interpretation of the facts, which implied, if it did not assert, that the Waverly and Marshall groups were only geographical modifications of formations of the same general age as the Chemung. Professor Winchell brought elaborate evidence to show that the Marshall, Waverly, and allied faunas in Illinois, Indiana, Iowa, and Missouri were equivalents, that they were not equivalent to the Chemung group of New York, and, finally, that they were separated from the latter by the Catskill group of Eastern New York, which was regarded as following the Chemung and intermediate between the Devonian and the Carboniferous age.

The problem of chief interest to the general geologist awaiting solution in these regions is that of the equivalency, or even the interpretation of the true relations, of these several series of rocks between the Hamilton and the Coal Measures, especially in the contiguous States of New York, Pennsylvania, and Ohio.

In the earlier surveys the Upper Devonian was traced far into the interior, and the Waverly of Ohio, the Burlington sandstone, and the Chouteau beds of Missouri were alike regarded as equivalent to the New York Chemung.

In 1867 Professor Hall receded from this position and recognized the force of Professor Newberry's discovery of *Spirifera Verneuili* (= *S. disjuncta*) below the Cleveland shale (see Geol. Surv. N. Y., Pal., Vol. IV, Pt. I, note at beginning). In 1870 the superior and independent position of the Waverly and equivalents was defended by Professor Winchell in the paper above mentioned.

VIEWS ON THE RELATION OF THE WAVERLY TO THE NEW YORK SERIES.

In 1875, Professor Hall, finding the fossils of the Chemung group in the higher beds of Western Pennsylvania mingling with other species regarded as Carboniferous, concluded that "the Chemung fauna contin-

ued its existence till after the appearance of Carboniferous forms, and that the two faunas, if they can be properly so regarded, lived in the same sea and at the same epoch; and the question of the limits between Devonian and Carboniferous formations is likely, at least for some time, to remain undetermined in some parts of the country." (Am. Jour. Sc., 3d ser., Vol. XII, pp. 303, 304.)

In 1878 Professor Newberry defended his early opinion regarding the Ohio equivalent of the Chemung as terminating at the base of the Cleveland shale (see Geol. Surv. Ohio, Vol. III, Geol., p. 14); but this opinion is complicated by the further one that the upper part of the Portage group is the proper base of the Carboniferous series, making these disputed beds merely a base of the Carboniferous.

The confusion in regard to the fossils of these Upper Devonian beds leaves the matter of exact equivalency still in doubt. That is, the mingling of faunas which led Prof. James Hall to regard the Chemung fauna as continuing into the Carboniferous and Prof. J. S. Newberry to draw down the limits of the Carboniferous so as to include the Chemung and the Upper Portage has not yet been satisfactorily interpreted. We see then that this confusion and occasional blending of faunas were variously interpreted by those who gave the subject most careful study. The New York State geologist (Hall), without distinguishing the faunas, regarded them as blending, and he left the relations of the New York and western beds undecided. The Ohio geologist (Newberry), from his standpoint of a Carboniferous Waverly group, brought down the Devono-Carboniferous point of transition to the Portage sandstones of New York, thus including the Chemung group within the Carboniferous; while the Michigan geologist (A. Winchell), recognizing the integrity of his Marshall group formation, but finding still no equivalent fauna for it in the New York series, regarded it as the equivalent of the brackish or fresh water Catskill group, thus putting it above the Chemung group of New York as then defined.[1]

VIEWS OF PENNSYLVANIA GEOLOGISTS.

Since 1875 the Pennsylvania geologists, under Prof. J. P. Lesley, finding the fossils entirely unsatisfactory as means of determining the

[1] Since the writing of this paper, at the Philadelphia meeting of the American Association for the Advancement of Science, in 1884, Prof. James Hall communicated a paper entitled, "Note on the intimate relations of the Chemung group and Waverly sandstone in Northwestern Pennsylvania and Southwestern New York." (Proc. Am. Assoc. Adv. Sc., 1884, Part II, p. 416.) The paper is based upon a section in Warren County, Pennsylvania, made by Mr. C. E. Beecher and Mr. F. A. Randall. In this section the Chemung is regarded as running up to the base of the Waverly, and at the junction is said to be "the place of the Catskill," where "there is a hiatus which, in Eastern New York and Pennsylvania, is marked by the presence of measures having a thickness of from 3,000 to 5,000 feet" (p. 418), and Professor Hall concludes that "the deposition of the estuary Catskill sediments has been going on simultaneously with the open sea deposits of the Waverly formation."

transition beds, adopted stratigraphical conditions as their chief criteria, and Mr. John F. Carll, Prof. I. C. White, Mr. C. A. Ashburner, and Mr. H. M. Chance have given in their several valuable reports various interpretations of the series.

The one point in which they all appear to agree is the equivalency of the Olean-Garland-Ohio Conglomerate, although in 1876 Mr. E. B. Andrews, formerly of the Ohio survey, objected with strong argument to regarding the Conglomerate underlying the Coal as marking a common horizon for even the Ohio-Pennsylvania-Virginia area, and suggested that it would be more appropriate to call this a rock than a common horizon. (See Proc. Am. Assoc. Adv. Sc., Vol. XXIV, Pt. II, p. 84.) The Pennsylvania geologists, taking this Olean Conglomerate as a definite common horizon, recognize a sub-Olean Conglomerate, which in their northwestern counties takes its place below the Olean Conglomerate and above the horizon to which the red beds of the east and their equivalents are assigned. This lower Conglomerate, often merely a sandstone, is distinguished by its flat pebbles, although frequent sandstones and conglomerates are recognized below, having flat and worn pebbles.

When we go below this horizon confusion is greater the greater the number of counties whose sections are compared, but in the northwestern counties, where the red beds offer least trouble by their presence, frequent heavy sandstone beds separated by shales and thinner shaly sandstones are found occupying at least several hundred feet. These have gained the more general name of the Venango oil sands.

Mr. J. F. Carll (Report III, Second Geol. Surv. Pa.) gives several systems of sandstones and shales below this before reaching what he regards the equivalents of the New York Chemung. Prof. I. C. White (QQQQ, 2d Geol. Surv. Pa., 1881) regards the Venango group as resting immediately upon Chemung flags in Erie and Crawford Counties, Pennsylvania, and is obliged, also, to recognize the fact that the fossils of this group are decidedly of Chemung type. This Venango group is included by Mr. C. A. Ashburner in the Catskill (Ponent, No. IX), but he includes the Bradford oil sands, which were placed higher in the series by Mr. Carll, in the Vespertine No. VIII.

THE PENNSYLVANIA SECTION.

Without entering into the minutiæ of the extremely interesting series of sections which the Second Geological Survey of Pennsylvania has brought to light, we find a general agreement in the following arrangement of deposits for the Upper Devonian, leaving out the red beds, which must receive special consideration. After passing the Hamilton formation and the black Genesee shale, where they are recognized, there is—

First. A series of thin bedded deposits, generally more argillaceous than sandy, constituting the blue or green shales of the Portage group, containing little or no iron, except in the condition of pyrites.

Second. A series of similar shales, but of generally lighter color and

weathering brown to yellow from iron oxides, and with occasional thick massive beds of light gray sandstones, often coarse grained and in places conglomeratic, and holding petroleum in some areas. When seen on the surface they are often strongly calcareous, and generally give off a strong bituminous odor upon first fracture.

Third. A series of sandstone conglomerates, with soft shales, not strongly separated from the second group, but the two kinds of rock, the shales and the sands, when interstratified, are each purer in composition, and the iron appears in beds or nodules in the sands, where iron oxides are so frequent as to cause them generally to be of a yellowish tint. Flat pebble conglomerate is seen in some of the beds.

Fourth. The coarse round pebble conglomerate, with thin seams of black shales and true bituminous coal.

THE ALLEGANY COUNTY SECTION.

In New York I find the Allegany County section bears a general resemblance to the Pennsylvania series. However, in the second group the sandstones are less prominent and the shales prevail, in the second and third groups the conglomerates are rare and generally only the sandstones are seen, and black shales are interleaved with the shales of the first group nearly to the base of the second. Going farther east in New York, I find the massive sandstones of the second group are reduced to but one or two beds of 2 or 3 feet thickness; and still farther east, but before reaching the Catskill Mountains, this particular class of sandstones is wanting, while the third series, in place of gray sandstones and conglomerates, becomes dark greenish gray, micaceous flags and red shales and sandstones; and, finally, the red and coarse, greenish gray, flaggy sandstones and shales appear still lower and fill the whole interval from the Hamilton shales upward to the Conglomerate.

ORDER OF DEPOSITS IN OHIO.

Now, turning in the other direction, in Ohio we find a different order of strata. The first group, instead of being followed by the heavier and more frequent sands of the second group, is followed by a return of the condition below, black fine shales and soft greens taking the place of thin bedded shales and sands. And the whole interval of the second and third groups of the areas farther east is represented by only one, at greatest only two, of the sandy conglomerate deposits.

The explanation of this condition of things is to be fully determined only by the fossils. I find that the first group holds a Portage fauna in the soft green shales and a Genesee fauna in the black interleaved shales. I find the second group marked by the departure of the Portage fauna at the first massive sandstones; and with the deposition of those sands of the second group, both in them and in the accompanying shales which are *more ferruginous* than those below, the Chemung fauna appears.

With the deposition of the lower flat pebble conglomerates, a new fauna comes in, but it does not entirely take the place of the other fauna. These first conglomerates are clearly shown to be comparatively local, grading rapidly off into coarse sands or even lost entirely in sandy shales in a distance of fifty miles. But their general place in the series is definite and regular in this eastern area. Also, so far as the facts are gathered, it is clear that the faunas associated with them are distinct, even when they were deposited alternately with Chemung shales bearing the genuine Chemung faunas.

In New York the flat pebble conglomerate appeared before the cessation of the Chemung fauna, and in fact we find traces of the latter up to the base of the Oleau Conglomerate.

The exact equivalency of the Ohio grits and overlying shales and their faunas must be determined by a fuller and more thorough comparative study of their faunas than has yet been published.

GEOGRAPHIC AND CHRONOLOGIC RELATIONS OF THE FAUNAS.

It is necessary to recognize the effect of geographical condition upon faunas, as well as the changes incident to chronological sequence, if we would interpret the confusion existing in the Devono-Carboniferous deposits of the eastern portion of our continent. But the assigning of the Marshall fauna to the period of the Catskill group does not settle it. Neither does the expansion of the Chemung to receive the Waverly fauna or the pulling down of the Carboniferous to cover the Portage relieve us from the main perplexities.

It is only by disentangling these faunas and ascertaining the true geographical and chronological relations which they bear to one another that the difficulty is to be met. This is to be attained, not by clinging to any sharp limits of a stratigraphical or a lithological nature or to any absolute division between one formation and the following, but each fauna must be traced upward and downward and its modifications noted until it is replaced by another, and whatever on the way is interpolated or is added to it must be traced to its origin or to its center of occurrence. Thus, I believe, a scale of the chronological sequence in the life history of the organisms and the faunas may be prepared which may serve as a definite standard for determining the relative age of deposits, quite independent of the characters of the sediments which were being continuously thrown down, these being in main part determined by local conditions of the disintegrating shores and the distance away from them. By themselves the rocks, as rocks, present no features which may serve as indications of the particular stage in geological time at which they were deposited.

While the method proposed will make of geology a more difficult and complex study, the entangling of formations and their groups of organisms—inextricably, as it would seem, when the attempt is made to make minute comparisons over wide areas—is much nearer a true ap-

preciation of the facts as they actually occurred than the simple but concise tabulation of typical series and the co-ordination of those that are not typical by thinning or thickening them with assumed gaps or insertions. The method of critical and careful study of the lithological and stratigraphical condition of the rocks, adopted by the Pennsylvania geologists, is bringing out with great distinctness the untrustworthiness of these characters alone for the co-ordination of horizons over any considerable extent of territory. The study of fossils in their relations to the rock deposits and in their association with one another has already suggested that the sharp lines, often observed separating one group of organisms stratigraphically from another, are in part due to local conditions. As our familiarity with different sections from separated areas increases, the faunas which we shall learn to regard as marking a common geological period or stage will comprise, in some measure at least, groupings of species as various as are now met with in the different regions and at different depths of the sea.

In this report the Upper Devonian, including the Genesee shale, comes under detailed discussion. The lowest member of this section is at Attica, Wyoming County, N. Y. Running northward from there the country is heavily covered with soil and no good exposures of Hamilton rocks are met with, and not till the limestone ridge seen at Batavia is reached have the rocks resisted disintegration sufficiently to present fit outcrops for study. Westward from Attica the Hamilton and the Marcellus are exposed, but all this part of the Devonian is far better represented fifty or a hundred miles farther east.

LIST OF THE FAUNAS.

The more important groupings of species into temporary faunas are: The *Lingula* fauna of the Genesee shales, as seen in section 468 (p. 31); the *Cardiola* fauna of the Portage shales, 472 C (p. 41); the early *Leiorhynchus* fauna of the green shales of the Chemung, 476 G (p. 60); the *Spirifera mesocostalis* fauna, as seen about Rushford, 476 (p. 58); the *Streptorhynchus* and *Spirifera disjuncta* fauna proper, as seen in the Cuba sandstones and similar sandstones to the north, 477 (p. 65); the lamellibranch fauna of a member of these sands, 477 A³ (p. 64); the *Lingula* fauna in the underlying shales, 477 A² (p. 64); the *Athyris Angelica* fauna, particularly represented in the soft shales, 477 H (p. 67); the fauna of the flat pebble conglomerate, 486 (p. 91), and the fauna of the ferruginous sandstone (p. 87).

Besides these there are a few local or special faunas, as a brownish red sandstone above Rushford (p. 56), containing a small terebratuloid shell, which appears identical with *Centronella Julia*, of Winchell, and the special fauna of one of the earliest red bands south of Cuba, with an abundance of a small *Orthis Leonensis* (p. 67).

Each of these several faunas is distinguishable as a separate group of species, associated with some distinct character of sediment or definite

horizon. Many of them were probably living at the same time within the same general oceanic area, but one was confined to mud bottom, another to sand, one is peculiar to a black shale, another to a soft green shale, a third to a sandy conglomerate. Several of them may contain a majority of the species alike, but hold some one or more species either peculiar to it or in greater abundance or under some particular varietal form. As we approach the top (it may be in some thin stratum differing from the surrounding deposits) we come across a little colony of a species foreign to the general fauna but characteristic of some formation of a different geographical area, as in the case of *Centronella Julia* in the Rushford sand (p. 56); or we may find in a series of apparently identical deposits two distinct faunas, having scarcely a species in common, though within a few feet of each other, as in the Lamellibranch and the Brachiopod faunas of the Cuba sandstone (p. 65).

RELATION OF THE FAUNAS TO THE CHARACTER OF THE DEPOSITS.

By thus disentangling the species and learning their habits of association and their relations to the sediments in which they were buried, the data are gathered for recognizing the faunas in other localities and in deposits where the prevailing lithological character may be so unlike as to give no suggestion of a common horizon.

In the more eastern section, at Cayuga Lake and southward, the black shales are confined almost entirely to the first horizon of the Genesee shale; slight traces of a dark but no black shale are recognized for a few hundred feet above. A rich fauna, the Ithaca fauna, is found in that section before the termination of the Portage fauna, but in its species it resembles both the eastern Hamilton fauna and the true Chemung fauna. The study of its species, and of those occurring above, proves that it represents an earlier stage than that of the Chemung fauna, and that it lies *below* as well as above deposits containing the genuine Portage fauna.

In the more western section of Wyoming and Allegany Counties the black shales recur frequently above the Genesee shales, and are interleaved with the regular Portage shales upward for a thousand feet from their base, each successive stage less distinct and more blended with the contained sediments. This fauna holds on till after the appearance of the Portage shales and its fauna, but becomes less and less apparent with each recurring stage until nothing is left but the *Sporangites*, which was doubtless an efficient cause of the dark color of the shales. Not a trace is seen of the Ithaca fauna. The Portage shales and fauna and the black shales occur in alternate deposits, the latter prevailing at first and the former being more prominent in the upper part of the series, up to the appearance of the first traces of the Chemung fauna.

The first introduction of the Chemung fauna was associated with the deposition of the gray sandstones generally called Portage sand-

stones. In their typical display at Portage Falls these sandstones are barren of fossil remains. But in tracing the Portage rocks upward I find a gradual increase in the arenaceous ingredients of the sediments. The Portage fauna belongs to the argillaceous deposits and in the upper part is scarcely ever detected except in some thin streak of soft, green shale interstratified with the more common thin bedded, arenaceous shales. The arenaceous shales, by the dropping out of the argillaceous streaks as we ascend, become thin sandstones, which increase in thickness, until finally at the top we have thick, massive sandstone separated by barren olive shales. These sandstones terminate the deposits containing Portage fossils and begin the series of the Chemung group. In this section, too, the black shales reach up to them but not beyond. It was clearly shown, by the work of this year, that the Chemung fauna coming in with the gray sandstones is the regular successor of the Portage fauna, and that the black shales and their special fauna are independent of both and only locally occupy the position in the series here recorded.

Farther to the east the succession of the Chemung fauna upon the Portage is substantially the same, but the black shales had entirely ceased some eight hundred feet below the point of transition.

RELATION OF THE BLACK SHALES TO THE UPPER FAUNAS.

In the extreme western part of Wyoming County a thin sheet of black shale was found immediately under the first sandstone bearing *Spirifera disjuncta*, an undoubted representative of the Chemung Brachiopod fauna (see p. 49); but only a few miles farther east, at Portage Falls, the first sandstones, although following pretty closely the termination of the black shales, contain no trace of the Chemung fauna. We are led to believe, therefore, that with the progress of the Upper Devonian the black shales were gradually withdrawing westward, and that the conditions producing them were independent of the causes producing the argillaceous and sandy shales associated with the Portage and Chemung faunas.

If the same rate of withdrawal of the black shales which is noted on passing from Cayuga Lake to Wyoming County continues on passing farther westward, the black shale should be expected to recur above the equivalents of the Chemung period, or even above conglomerates, as we go westward. That the black shales of Ohio *may* be such a continuation of the shales occurring in New York was shown by the presence of the characteristic species of the Cleveland shale of Bedford Ohio, in the genuine Genesee black shale of Wyoming County.

As I stated in a preliminary report, an abstract of which has already appeared in Science (Vol. II, p. 836), the identity of the two faunas is not necessarily evidence of equivalency of horizon, but I interpret it rather as a fauna which may have persisted with very little change for

a long time, possibly during the greater part of the Devonian age, although as yet there is no conclusive evidence that the fauna of the Marcellus black shale was identical with this.

Future study may show the Cleveland shale, at Bedford, Ohio, to be identical stratigraphically with the higher recurrent black shale beds of the Portage of New York, but it is more probable that the fauna persisted with little change, and that the black shales were being deposited continuously (though not continuously in any one particular spot) in the great interior continental basin from the Middle Devonian to the time of the sub-Carboniferous limestones. Another fact brought out by these studies is that the sandstones, as we pass upward from the time of the reign of the Hamilton faunas, changed gradually from thin argillaceous sandstones or arenaceous shales of a dark color and flaggy structure, first to thicker beds with less clay, then into purer and more massive sandstones with slightly coarser grain and of a lighter gray without fossils; and, higher, become light gray sandstones, calcareous and generally fossiliferous, with the Chemung fauna, and, pretty generally, more or less saturated with petroleum.

The petroleum odor of those outcropping on the surface is proportionate to their porosity and freedom from lime.

PLACE OF THE VENANGO OIL GROUP.

From a study of Mr. I. C. White's sections of Erie and Crawford Counties, as given in Report QQQQ, Second Geol. Surv. Pa., it seems more than probable that his Venango oil group is identical with these Chemung sandstones. Comparison of their fossils alone can give conclusive testimony on this point. Mr. White's opinion is that the Panama conglomerate is equivalent to the third oil sand of Venango group (see QQQQ, Second Geol. Surv. Pa.).

Mr. Carll (in Report IIII, Second Geol. Surv. Pa.) still refuses to accept this interpretation, but he makes no positive identification and even suggests a plane of non-conformity. If the method adopted by the Pennsylvania survey were capable of solving this intricate problem, the careful and most industrious study given their rocks should have brought a more satisfactory solution than we at present have. It would be difficult to improve upon the stratigraphical data already accumulated.

If fossils prove as satisfactory in the more western deposits as they have proved in the New York Chemung they should decide, when carefully studied, whether a portion of the series is missing or whether the geographical change alone is to account for the changed faunas. But I reserve opinion until I can compare the fossils themselves and learn their associations.

STRATA FOLLOWING THE CHEMUNG FAUNAS.

Above the Chemung sandstones appear coarser sands with occasional streaks of worn pebbles, the larger sizes of which are flat and of a still

lighter gray color. They show decided traces of iron in the higher beds, each bed beginning or terminating, or both, with ferruginous beds composed of clay ironstone nodules in the midst of the sand. As these ferruginous sandstones are reached the Chemung fauna comes to its close and another series of deposits becomes dominant, which, in their purity, contained no marine faunas. They took the place of the Chemung series, but are not sharply distinct at the outset.

In the Allegany County section this new series of rocks began down among the deposits containing the Chemung faunas, first as thin streaks of red argillaceous shale, a little below the first gravel sandstones and ferruginous sandstones and conglomerates, and, at the stage of the latter, the red beds were of frequent occurrence, but rarely over a foot in thickness. These red beds were apparently the continuation, under changed conditions, of the olive shales of the Chemung, which contained a fauna differing in the characteristic species from the sandstones interstratified with them. At first the red beds held a few of the species of that fauna, but soon lost them and were utterly barren at every later stage of their recurrence.

Interstratified with the red, argillaceous shales and apparently taking the place of the sands occurring below, we find rather coarse, micaceous sandstones, generally very evenly bedded, the mica grains sometimes mingled intimately with the sand, causing a loose mealy structure; at other times the mica grains, almost pure, are laid out in thin sheets, making an imitation of schistose structure or forming very even, thin flagging. These micaceous sandstones have no fossils and are of a gray green to a dark green color, and when weathered are often peppered with dark brown spots, from the decomposition of minute ferruginous grains.

As we pass upward the red shales are more frequent and some layers become arenaceous, so that the mass of the deposits is of alternations of red argillaceous shales, red arenaceous shales and sandstones, and green micaceous sandstones and shaly sandstones.

At this stage some of the beds of olive sandy shale, with fewer and smaller grains of mica, contain large scales of *Holoptychius* and other fish remains, and ferruginous sandstones occur, with a restricted marine fauna which appears to be the successor of the Chemung fauna; and, finally, to close the series, a thick massive conglomerate appears, which, in this region, is called the Olean Conglomerate, composed of coarse silicious sand and coarse, rounded, but little worn, often large sized quartz pebbles.

It will be seen, in this brief review of the series of deposits, that the red and green shales and sands which take the place of the Chemung group and occupy the interval between it and the Olean Conglomerate are the equivalents of those thick deposits which form so prominent a feature in the eastern part of New York State and extend southward across

Pennsylvania, &c., where they are known as the Catskill group. They are feebly represented in the western part of New York, where the Upper Devonian is best represented. The thick deposits containing Devonian plants at St. John, New Brunswick, and in the northeast, are undoubtedly a northern extension of the same series, although beginning at a much earlier stage as measured by the progress of marine faunas.

In regard to the Catskill group, my studies have led me to believe that the Catskill red rocks of the east offer evidence of having been contemporaneous with a great portion of the Upper Devonian rocks, and a comparison of faunas, at least, goes to show that the base of the red beds does not form a definite and uniform horizon. Influenced apparently by the contrary opinion, Professor White makes a provisional upper limit for the Chemung group of Columbia County, Pennsylvania, at the lowest red rock, and calls the interval between this point and where the *Holoptychius* appears the Chemung-Catskill. (See Second Geol. Surv. Pa., G^7, p. 63.)

THE INTERPRETATION OF THE FACTS.

Taking the faunas as our criteria of chronological horizon, it seems more appropriate to speak of the red beds as appearing farther down in the Chemung group than to make a break in the series long before any permanent effect was produced upon the character of the faunas.

The interpretation given by the English geologists of the Devonian and Old Red Sandstone series is relevant here. The Old Red Sandstones, with their brackish water fish fauna and plants, are not successors of the Devonian beds with marine fauna, but are the equivalents of the whole series from the base to the top of the Devonian.

The Russian series clearly illustrates this point. Alternation is there seen of the two classes of deposits, the one containing the Devonian marine fossils, the other the sandy brackish water beds with the *Holoptychius*, even in association with the marine brachiopods of Upper Devonian species.

As we follow our Devonian series eastward, either in New York or in Pennsylvania, the lower position of the first red beds is conspicuous, and so long as the red sediments occupied the ground only temporarily we may suppose the marine conditions were not entirely cut off, and slight oscillations drove away and brought back the marine fauna over any particular area, but when the marine conditions were finally shut off there was a termination of the marine fauna. This shutting off of the sea took place earlier in the eastern than in the western part of this New York-Pennsylvania area, and there is reason to believe that in Sullivan County, New York, it was as early as the reign of the Hamilton faunas. (This was shown to be a fact in Chenango and Otsego Counties by investigations in 1885. Communicated to Am. Asso. Adv. Sc. meeting at Ann Arbor, Sept., 1885.)

The *Holoptychius* evidently found its congenial habitat in the midst of the red rock conditions. Its occasional appearance in strata below the termination of the Chemung fauna is rather confirmatory evidence of the actual presence in other geographical areas of those conditions from which the specimens strayed than evidence of any higher horizon than that indicated by the same faunas elsewhere.

In the Western New York area the gradual appearance of Catskill deposits was due to the encroachment of the land and fresh water conditions upon the marine basin in which the Chemung faunas flourished. The Chemung faunas continued to live there so long as the marine conditions were sufficiently pure to maintain their life, and I take it that there is nothing inconsistent in the view that Catskill rocks were being deposited in the Appalachian region at the same time that Chemung rocks were being formed over Western New York areas and during the reign of the Chemung faunas.

As the fossil faunas were traced upward in their successive stages, it was ascertained that, besides the changes occasioned by the dropping out of some species and the introduction of new species, the decreased abundance of common forms, or the increased abundance of others, there was also a change in the dominant varietal modification of the more common forms. Detailed report of these modifications coincident with range and distribution will be more satisfactory after a wider territory has been examined and a fuller series of species and specimens has been brought into comparison. But already some general remarks can be made as to the kind of changes detected.

In one species, *Spirifera mesocostalis*, ranging from the base of the Ithaca group high up into the Chemung, a great modification of form and size was observed. The prevailing type, at its earliest appearance, was small and with fine mucronate extension of the area; the later type, which was more abundant in the western than in the eastern section, was large and coarsely plicate, with great extension of the front, and, though with short mucronate hinge area, this feature is not prominent and this dimension of the shell is prominently short. Moreover, while the later modification is wanting in the earlier faunas, the earlier type still exists in the later faunas, but is relatively rare. A study of the species from a wider geographical territory will be required in order to determine how much these modifications are the effects of geographical conditions.

One modification of this species was found to be entirely coincident with geological range in the collections at command. This is the gradual appearance and final prominence of a median keel dividing the muscular impressions within the beak of the ventral valve. As this is one of the characters distinguishing the genus *Spiriferina*, it is interesting to note its gradual assumption as a purely varietal character of an undoubted *Spirifera*. This character is represented in Figs. 10 and 11 of Plate 40, Geol. Surv. N. Y., Pal., Vol. IV, Pt. I, and slightly in Fig. 2.

I have examined a large number of specimens, but among the earlier representatives from the Ithaca group rarely is even a trace of this character seen; an occasional specimen, however, shows a slight ridge dividing the muscular impressions. In the higher beds it takes the form of a strong median septum, but is less prominent in the small form associated with the prevailing type, but rare at that particular stage. Other representatives of the genus presented traces of the septum at an earlier stage.

Another change in type associated with the geological range of the species is seen in the case of *Orthis impressa*. In the lower part of the Upper Devonian (base of the Ithaca group) it differs little from the round, narrow form of *O. Tulliensis;* in its later stage it is particularly wide at the front, with a wide, pronounced fold and sinus, and of large size.

The *Lingulas* of the black, and later greenish, argillaceous shales present a regular series from the minute *Lingula spatulata* of the black Genesee shales, through intermediate forms, to the typical *Lingula Melie* of the Ohio black shales. In this area the larger form is attained at an early stage of the Upper Devonian faunas.

So far as at present observed, these varietal modifications of a specific type are at first represented by a few rare forms in the midst of abundant individuals of the typical form; and as we go upward the characteristic feature becomes conspicuous by being assumed by a greater proportion of the individuals of the species, and finally becomes the prevailing form, the original type then appearing only as an occasional variation.

A few facts brought out in the course of these studies may be noted in closing this chapter.

The *vertical fucoid* markings, as they are called, in the Portage sandstones and similar sandstones above, are evidently the borings of some kind of worm or boring animal; and these markings, whatever they were, characterize the Chemung sandstones of the Allegany County section up to the conglomerates of flat pebbles. Above this point, and often in the sandstones associated with the flat pebble conglomerates, a similar marking is seen in some of the sandstone layers; but the size of the boring is always smaller and shorter, generally about half as large in diameter, and the borings are arranged much more closely together. So that, although the organism forming them may have been of a similar nature, the upper one was undoubtedly of a distinct species. This fact, we think, may help in tracing the horizon of the upper fucoid-bearing sandstones (as a name for which I would suggest *Verticalis* sandstones) toward the west, where the fossils are rare.

Also, on comparing our Allegany section with those of McKean County, Pennsylvania, it appears more than probable that what Mr. Ashburner calls the sub-Olean conglomerate is the equivalent of the

ferruginous sandstone, which approaches very near the base of the Olean conglomerate, both at Olean and at Little Genesee, rather than the Allegany County flat pebble conglomerate, which is, more likely, represented at a similar position at Bradford below *Holoptychius* beds, but above the appearance of the Chemung faunas, and, on Mt. Raub, was recognized some three hundred feet below the Conglomerate in the outcroppings on the surface.

At Hornellsville, about half way between the Western New York section and that running through Ithaca, in Tompkins County, was seen a remarkable confirmation of the hypothesis advanced in regard to the position of the Ithaca fauna. Here was found exposed a section at the point of transition from the Portage to the Chemung fauna. The gray shales carrying the Portage fauna are preceded by a streak of black shale like the last representatives at Portage. With the Portage *Cardiola* fauna was found the first Chemung stage of *Spirifera mesocostalis*, with an *Orthis*, not the species common in the more western section, but the *Orthis Tioga* of the "Chemung" of the Cayuga meridian. Immediately following the *Cardiola* fauna, in shales more sandy and ferruginous in character, was seen the fauna of the lowest Chemung at Rushford, the *Leiorhynchus* fauna, with the exception that the eastern *Orthis* took the place of the common form of the Allegany rocks. This was followed above by more sandy deposits, containing the typical Chemung faunas. The altitude and the rocks exposed along the railroad all the way to Elmira leave no doubt of a position stratigraphically between six and eight hundred feet above the horizon of the Ithaca group at Ithaca. The transition from the *Cardiola* fauna directly to the lowest Chemung fauna is also unmistakable, and the *Orthis Tioga* is evidence of the genuine Chemung fauna of the eastern section as distinguished from the lower Ithaca fauna.

It furnishes evidence, therefore, that the transition from the Portage to the genuine Chemung formation is far above the Ithaca group, and that the fauna of the latter is an earlier stage, and intermediate between the Chemung and the Hamilton, and has no representative in the section in Wyoming and Allegany Counties.

CHAPTER II.

FAUNAS OF THE GENESEE SHALE AND THE PORTAGE GROUPS.

The exposures of the Genesee shale are noticed first, on going southward, along the northern line of Wyoming County, and most of the exposures in the middle and southern part of the county are of the Portage group.

These include the following stations: 468 Attica, 471 Warsaw, 472 Varysburg, 473 Bennington, including 473 A, the Daubree quarry, and 473 B, the section at Sierk's station, and 475 Java.

Attica, Wyoming County, N. Y.—468.

Attica is situated 10 miles a little west of south from Batavia. After leaving the limestone ridge there are few if any good exposures of rock directly south until near Attica, where the first traces of the Black Genesee shale appear.

The Tonawanda Creek runs directly through the town of Attica, but below this point it runs through clay and gravel banks until reaching the limestones of the northern towns. The creek is dammed just under the railroad bridge; the altitude of the railroad at this point is about a thousand feet (998) above the sea. The bed of the creek below the bridge is black shale—a fine exposure of the Genesee shale. The dam covers its top, but, taking the railroad bed as a datum, I estimate that the top of the Genesee shale at this point is not far from 975 feet above tide level.

The bottom is not exposed; hence the thickness cannot be given.

Several exposures were examined in and about Attica, giving sections 468 A, B, C, D, E, and F. A combination of these several sections gives us a very fair representation of the general character of the base of the Upper Devonian for this region.

The Genesee shale is a black bituminous shale, when freshly broken giving out a strong odor of petroleum, and with dark brown scratch. It is very evenly bedded, compact, and when fresh from the quarry is massive, with a conchoidal fracture. Upon weathering it becomes more fissile, but is generally a very fine uniform shale, withstanding the weather a long time without showing tendency to fissile cleavage. It is seen best in 468 B. The fauna of this exposure (468 B) of the Genesee black shale is as follows:

Lingula spatulata, varying from the minute, sharp beaked form characteristic of the Genesee shales to the wider, more oval form of the Cleveland shales, Bedford, Ohio, called *L. Melie* and *L. subspatulata* by Ohio paleontologists.

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Sporangites, the same forms as those of the Ohio black shales.

Conodont teeth, identical with and including the majority of forms figured by Professor Newberry in Rep. Geol. Surv. Ohio, Vol. II, Pt. II, Pal., Pl. LVII.

Palæoniscus scales.

This fauna, therefore, agrees closely with that of Professor Newberry's Cleveland shale of Bedford, Ohio. The broader variety of the *Lingulas* is not only plainly a mere variation of the typical *Lingula spatulata*, but is quite indistinguishable from specimens of the *Lingula* of the shales at Bedford, Ohio, with which I have carefully compared it. The Bedford specimens are generally of larger size, but those of the same size agree in form, convexity, and surface markings for the two localities.

In the olive shales underlying the Cuba sandstones are seen *Lingulas* which agree also in average size with the ordinary *L. Melie* of Ohio.

The close agreement in the species and in the combination of species in these two zones leads us to the opinion that we are dealing with the same fauna in the black shales of Genesee in New York and at Bedford and Chagrin Falls in Ohio, although the evidence has not appeared to prove that the horizons themselves are synchronous.

The Genesee shale is followed by a soft argillaceous green shale, with Portage fossils. Toward the upper part there are some calcareous layers and an occasional thin layer of arenaceous shale. Then comes a second black shale, which is again followed by greenish shales; this by another black shale, and so on for at least several hundred feet.

It is an oscillation between two principal types of deposit, each of which becomes gradually modified in the same way as we ascend the series:

First, the black shale in its pure condition seen in the Genesee shale.

Second, the green argillaceous shale characteristic at the base of the Portage.

These two alternate with each other, and with each change, as we ascend, the green shale increases and the black shale decreases in amount. The black shale at each stage of its reappearance is more arenaceous, assumes a decided iron stain upon weathering, and also weathers quickly to fine fissile chips, which, in the lower beds, long resist further disintegration, but in the upper beds have not the power of resistance and soon are reduced to soil. In the first reappearance of black shale above the Genesee shales there is still a strong petroleum odor upon fresh fracture, and when fresh from the quarry the appearance of the shale is black, massive, capable of conchoidal cleavage, and scarcely distinguishable from the Genesee shale below. But upon weathering it quickly reveals the presence of inequality in the minute constitution of the deposit, causing it to cleave into thin flakes. These first Portage black shales exhibit their relation to the Genesee shales below by the presence of the same fossils.

Lingula spatulata was taken from the black shale fully 100 feet above the Genesee shale, separated from it by the green argillaceous shales with a characteristic Portage fauna.

Higher up the black shales rarely contain a single fossil. The green shales show the same gradual change from soft, fine, argillaceous material to coarser, more arenaceous, and more irregular strata; in the upper part the sandstone masses are interstratified with the softer argillaceous shales. There is also a change in the color; the lighter green shales are more prominent in the lower part, and the black shales lose their color on going upward, till finally they are scarcely distinguishable from the accompanying arenaceous shales of the Portage group.

468 D is a cut in a gorge southeast of the village of Attica, about two miles distant. The first rock exposure of the cut is, approximately, 1,200 feet above sea level. Stratigraphically it begins somewhat above the top of 468 C^3, perhaps over 100 feet. But 468 E is below its base and represents the intervening part of the section, although it is difficult to determine the precise equivalency of the individual strata in the several ravines. The strata are composed of alternating masses of black and soft green shales. The lower part of the series presents thicker masses of black, and as we go up the black shales are less strongly marked, more arenaceous, and each succeeding mass is thinner than the preceding.

The cut 468 D^1 to D^{11} represents something over 200 feet of strata and at the top the green shales entirely replace the black. D^3 is the lowest seam of black shale in this cut; it is very similar lithologically to the first black seam above the true Genesee shale and is but a few feet thick; its termination is not exposed, but when the next exposure appears in the bed of the stream it is the gray green shale again; it contains *Sporangites* and *Palæonicus* scales, but no *Lingulas* or *Discinæ* were discovered. D^4 is a gray shale, rather massive and hard, followed by a second black shale containing *Sporangites*. A little higher, D^5, gray shales predominate, but with thin layers of dark shale, not so black as those below; but along in this part of the cut, for 100 feet, the light gray green shales carry *Sporangites* and *Styliola*, the former very distinct in the light colored strata. In D^6 are some soft, argillaceous, light gray green shales, still showing traces of *Sporangites*. *Styliola* also appears in the soft, light shales at D^7. At D^8 the thin black layers are conspicuous again and hold *Sporangites*, but the gray soft shales prevail and carry the same fauna. At D^9 the black layers have disappeared, and from this point upward only dark bluish strata alternate with the prevailing gray green shales. In the darker parts *Sporangites* are occasionally seen. With the ceasing of the black streaks the Portage fauna begins to reappear. Small aviculoid shells and *Cardiola speciosa* are the first to be recognized at D^9, with *Styliola*. At D^{10} the shales are light olive in color and soft, argillaceous, and quickly weathering into soil; in this stratum *Cardiola speciosa* is conspicuous; *Pterinopecten*

Atticus, n. s., *Leperditiæ*, the broad variety of *Lingula spatulata*, a small imperfect *Pleurotomaria*, a crinoid stem half a centimeter in diameter, and a minute *Chonetes lepida* constitute the fauna, so far as discovered. A little higher, $D^{10\frac{1}{4}}$, the shales are decidedly arenaceous, and from there to the top of the gorge the shales are harder and coarser and the olive tints are replaced by bluish and darker grays. At D^{11} *Cardiola speciosa* appears with a *Hyolithes* and *Goniatites* and some new forms. All the species of this cut are small, delicate forms, and are nowhere abundant, but require very close, careful search for their discovery. Enough, however, was found to demonstrate the general relation of the faunas to the deposits containing them.

It is evident, from a study of this series in connection with 468 A, B, and C, that the deposits from the base of the Genesee shale, for several hundred feet at least, are the result of oscillating conditions which brought from one direction the black muds, highly bituminous in nature, and from another direction light gray muds, at first very fine and argillaceous and later mixed with coarser, silicious particles.

The *Palæoniscus* scales are peculiar to the black shales. The *Sporangites*, although characteristic of the black shales, are not confined to them so long as they were in the neighborhood, as is shown by their occurrence in the light, argillaceous shales interstratified with them, but when the black shales finally withdrew from this locality the *Sporangites* ceased.

The *Lingula spatulata* is peculiar to the soft, argillaceous deposits, most abundant in the bituminous shales, and there typically represented; in the light colored shales only the broad and larger variety appears.

The other species, the *Cardiola speciosa*, the *Aviculas*, the *Pleurotomaria*, the *Chonetes*, the *Leptodesma*, the *Hyolithes*, and the *Goniatites*, belong to the fauna of the gray shales, rare in the pure, argillaceous sediments, but more abundant as the silicious and coarser muds were depositing.

Leperditia and *Styliola* may have been common to both faunas; the former was rare. Other evidence shows the latter to be more abundant in the black shales.

The Cardiola Fauna—468 A.

The following species have been identified in the soft, argillaceous shales at the base of the Portage:

Cardiola speciosa,[1] abundant.
Styliola fissurella, abundant in some layers.
Goniatites uniangularis Conrad several specimens, small.
Goniatites complanatus.
Lunulicardium fragile.
Lunulicardium levis, n. sp.
Coleolus acicula.

[1] The generic name *Glyptocardia* has been proposed for this well known species by Professor James Hall (1885). (See Pal. N. Y., Vol. V, Pt. I, Lamell. II, p. xxxv.)

Sporangites, rare.
Lingula spatulata, the broad variety, a single specimen.
Pleurotomaria ? capillaria, fragments.
Leperditia, sp., a few impressions.
Aptychus of *Goniatites ?* of *G. uniangularis.*
Aptychus ? or *Spathiocaris ?* (Clark), fragments marked like *S. Emersoni*, but broken so that the shape is not shown.

In similar shales, but calcareous (C^2), there are, besides the *Cardiola*, *Calceola*, and *Styliola*, which are the more frequent forms, a small *Orthoceras* and a *Palæoniscus* scale of larger size than those in the black shales; in another exposure, a small *Loxonema ?*, not preserving the exterior, but resembling the terminal portion of *L. delphicola.* The *Styliolas* often occur in elongated masses, which weather a yellowish brown from iron stain, and the shape of the masses suggests a possible coprolitic origin.

DESCRIPTION OF TWO NEW LAMELLIBRANCHS.

Pterinopecten ? Atticus, n. sp. Plate III, Figs. 10, 11.

This is a small species, with subquadrate form, hinge line straight and shorter than the greatest width of shell, ears small and indistinctly defined. The middle portion of the surface marked by irregular, rounded, radiate folds or plications, which bifurcate and are more conspicuous toward the front; the sides are either smooth or faintly marked by fine radiate striæ. Concentric lines of growth are apparent over the whole surface, but not strong. The beaks are prominent, slightly arching over the hinge margin. The wing is not produced into a mucronate point, as in most of the Pterinopectens, nor is it shortened, as in the Lyriopectens. The anterior ear is separated by a rounded sulcus and fold, but is not sharply defined. The posterior wing is much as in Lyriopecten.

Dimensions of medium sized specimen: Length, 6.5^{mm}; width, 5.4^{mm}.

Horizon and locality: The soft, green shales, Middle Portage group, Attica, N. Y.

Specific name from Attica: Lat. *atticus*, dwelling in Attica.

Ptychopteria ? mesocostalis, n. sp. Plate III, Fig. 9.

A small pterinoid shell, oblique, similar in form to some of the smaller shells of Hall's genus *Ptychopteria* (see *P. Proto.*, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Pl. XXIII, Lamell. I), but marked across the middle by irregular rounded radiate folds, the sides by faint and finer radiate striæ. The anterior wing separated by a sulcus and fold, the posterior wing moderate, without mucronate extension, the ventral margin slightly concave and posteriorly broadly rounded into the posterior margin. With concentric rounded lines of growth.

In its details this shell is marked almost exactly as the erect forms, found in the same rocks, which I have called *Pterinopecten Atticus.* I do not find intermediate forms. The only definable difference could be ac-

counted for by the development of this shell more obliquely and rapidly in the direction of its umbonal ridge.

I am constrained, after much study of the material at hand, to regard the specimens, like Fig. 12, as a smoother and extreme variety of this species, although this would be more appropriately called a Leptodesma, except for the radiate striæ of the surface. These three forms, figured as 9, 10, 11, and 12 of Plate III, could be taken as types of three species, and even three distinct genera if we were to follow some of the modern usages in describing them. While I refer them provisionally to two distinct genera I believe that they are closely allied, and that they should all be included in the same genus, but that genus is neither of those named as they are now defined, but should be bounded by different characters. The present classification of *Pterinea* Goldfuss into the genera *Actinopteria* and *Ptychopteria* on the one side and *Leiopteria* and *Leptodesma* on the other, used in the fifth volume of the Palæontology of New York, leaves practically no characters for the differentiation of the species concerned, except those of contour and general form, and whenever I have seen these species in abundance in the same locality the variations in both of these particulars are so considerable that it is difficult to believe that the division into so many species as are defined is either judicious or will be of any use to science further than giving a thorough illustration of the plasticity of this type of shells. At a future time I hope to discuss this subject more fully.

Warsaw, Wyoming County, N. Y.—471.

This station is ten miles southeast of Attica (468) and nine miles east of Varysburg (472). The town is in a valley with hills, both east and west, rising over three hundred feet. The altitudes are, for the New York, Lake Erie and Western Railroad station, 1,326 feet above tide; for the Buffalo, Rochester and Pittsburgh Railroad, on the west side of valley, 1,117 feet above tide. The post office is reported by surveyors of the place to be 1,017 feet above tide. The hillsides are cut by several ravines, exposing two or three hundred feet of rock outcrops.

Crystal Brook, Warsaw.—471 A.

This ravine cuts down the hillside a little northeast of the village. The first rocky exposures may be 1,050 feet above tide, and they were examined upward about two hundred feet, to the first solid sandstone under the New York, Lake Erie and Western Railroad, at an altitude of approximately 1,250 feet.

The whole exposure is composed of thin bedded deposits of argillaceous and arenaceous shales, with occasionally a stiff, thin seam of flaggy sandstone. The prevailing colors are blue gray near the bottom; the softer, more fissile shales are more greenish or olive. The general characters resemble very closely those of 468 D, with the exception of the absence of black shales. No sandstone strong enough to form any con-

siderable fall is met with till we reach the top, and this seam is gray, but finer, harder, and more flaggy than the typical Portage sandstones. It is, however, calcareous. No traces of the *Verticalis* borings were seen. Underlying it are some soft, greenish shales, some layers of which are nodular. Under these are darker blue shales bearing the same fauna found in the upper part of 468 D.

Omitting the consideration of the black shales and comparing the general character of the deposits and their fauna (that is, the olive shales gradually changing into bluish and more arenaceous deposits, with flaggy and wave marked structure, as we ascend), I should regard the base of this section as occupying a stratigraphic position somewhat higher than the top of section 468 D.

The aviculoid shell *Pterinopecten Atticus*, abundant at 468 D^{10}, at an altitude of 1,340 to 1,350 feet, is identical with the species most abundant in the Warsaw station 471, at an altitude of about 1,200 feet. The following 100 feet of the Attica section (468 D) takes us up to sandy and flaggy deposits; in the same way the upper deposits of 471 are sandy and flaggy, following soft, light colored shales.

The species of 471 A^3 are —

Cardiola speciosa, abundant.
Lunulicardium levis, n. sp.
Styliola fissurella, rare.
Pterinopecten? Atticus, n. sp., abundant.
Ptychopteria? mesocostalis, n. sp.
Sporangites, rare.
Euomphalus?, a fragment.
Goniatites uniangularis.
Fragments of crinoid stems.
Coleolus ?acicula.
Aptychus of *Goniatites*. Plate III, Figs. 3 and 4.

The specimens figured are of a small, thin, scale-like fossil, black when the substance is preserved, and apparently chitinous originally. In outline it has the shape of a transverse section of the outer chamber of *Goniatites*, like *G. bicostatus*, and of the same size as would fit such specimens as have been found in the same horizon.

The shorter specimen (Fig. 4) may belong to a more closely coiled species, like *G. uniangularis*, which also is found in the same rocks.

The more perfect specimen (Fig. 3) is 8.3^{mm} long, 5.2^{mm} wide, and the depth of the rounded sinus is 2^{mm}. This is supposed to represent the groove formed by the inner coil of the shell partly inclosed by the outer lining chamber. The *Aptychus* is not flat, but transversely arched, the arching confined to the central portion, and marginally it is nearly flat. I find no reason to doubt that this was an *Aptychus* of one of the *Goniatites* so frequent in the Portage rocks, and in size and form it agrees very closely with the figures in Keyserling's Wiss. Beob. Reise

Petschora-Land, Pl. 13, Figs. 3–7, and referred by him to *Aptychus* (see pp. 286, 287, and Fig. 5 particularly). The specimens were from the concretions in the Dominick black shales. It is one of the same class of objects referred to *Cardiocaris* by H. Woodward, Geol. Mag., London, vol. 14, p. 386, and to *Spathiocaris* by J. M. Clarke (Am. Jour. Sc., Vol. XXIII, 3d ser., p. 477). The recent discoveries of Kayser, Dames, and Woodward leave no doubt of the *Aptychus* nature of some of the so-called phyllopod crustacea of the Silurian and Devonian.

The specimens here figured are of the type called *Anaptychus* by Offel and belong to the group *Simplices* of Zittel's classification (Paleont., Vol. I, Part 2, p. 403), consisting of a single piece. It is probable that all the forms from the Portage rocks described by J. M. Clarke as *Spathiocaris* and *Cardiocaris*, and possibly some other genera, are of a similar nature. (See Dames, Zeitschrift d. deutsch. geol. Gesellsch., 1882, Vol. XXXIV, p. 819; Neues Jahrbuch, Bd. I, 1884, p. 178; and Woodward, Geol. Mag., Dec. III, Vol. II, 1885, p. 345, and Plate IX.)

Lunulicardium Munster.

Several specimens from the green shales of the Lower Portage group are referred, after considerable study, to the genus *Lunulicardium* as restricted by Zittel (Handb. d. Paleont. Vol. I, Part 2, p. 36) and as applied by Hall (Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II) to such forms as *Avicula fragilis* Hall of the Geol. Report, 4th dist. N. Y., p. 222.

The specimen figured on Plate III (Fig. 7), on careful comparison with genuine examples of *L. fragile* from the Marcellus shales and higher, is found to be indistinguishable, except in its more gibbous form, which is ascribed to its better preservation through the possession of a thicker shell. The typical forms of *L. fragile* were evidently very thin and are found in the fossil state crushed very flat, but always with more or less wrinkled surface. These Portage specimens occasionally show fine radiate striæ on the surface, a character recorded as appearing on well preserved specimens of *L. fragile*.

In the more oblong forms (Plate III, Figs. 5, 6, and 8) the fine radiate striæ are pretty generally visible upon magnifying the surface, and the position, length, and direction of the byssal fissure are those of *L. fragile*. In one specimen (Fig. 8) the lip of the byssal gap is reflected, as in well preserved specimens of *L. fragile*, but in another specimen (Fig. 6) of the opposite valve the lip of the opening is inflected, as in some of the *Limas*. The latter appears to be a right valve and the former a left valve.

In each of the oval specimens opposite the byssal opening is a very small angular extension of the cardinal margin, upon which are two or three sharp radiating plications or lateral cardinal teeth. In this feature they recall such forms as *Mytilarca* (*Plethomytilus*) *oviformis* Hall of the Hamilton group (Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II, Pl. XXXI, Figs. 7 and 8), but the direction of growth and the curvature

of the shell and direction of the beak are distinct. The cardinal angle is also much more prominent in that species. While there appears reason for regarding the shells under consideration as allied to the *Mytilarcas*, as may possibly be also the *L. fragile*, taking all points into consideration they fall more naturally under the genus in which *L. fragile* is found.

I propose for specimens figured on Plate III, Fig. 6 and Fig. 8, the name *Lunulicardium levis*, and refer provisionally to the same species the larger form, Fig. 5.

DESCRIPTION OF LUNULICARDIUM LEVIS.

Lunulicardium levis, n. sp., Pl. III, Figs. 6 and 8.

Shell medium size, obliquely oval, with sharp, short beak nearly central, with byssal gap starting close under the beak on the anterior side and reaching obliquely about one-half the length of the shell, lip reflected in the left valve and inflected in right valve, the front broadly rounded and curving around regularly to near the beak on the posterior side, where is a slight angular extension of the hinge margin, upon which are two or three well defined radiating plications which may be lateral cardinal teeth. Surface nearly smooth, with concentric lines of growth and very fine, radiate striæ.

Dimensions: Length, 20^{mm}; width, 15.2^{mm}; length of byssal fissure, 12.9^{mm}; angle of byssal lip with central axis of shell, 40° to 41°.

Horizon and locality: The green shales of the Lower Portage group at Varysburg and Warsaw, Wyoming County, N. Y.

Varysburg, Wyoming County, N. Y.—472.

At Varysburg three sections were examined, 472 A, B, and C. The position of this station is about seven miles south and a mile or so west of the Attica station 468. The altitude, estimated by railroad grade, is 1,239 feet above tide level. The bridge across the Tonawanda Creek in the valley is approximately 1,121 feet above tide level. Along the banks of the stream some thick layers of black shale appear, with interstratified masses of the olive Portage shales. But we are here near the top of the black shale deposits, the highest traces of which were 472 B^5 at 1,270 feet and a thin streak in section 472 C.

These are not pure black shales, but contain particles of pyrite and mica mingled with the arenaceous particles of the including strata, and they show traces of *Sporangites*. 472 C^0 is a more massive black streak of the same shale, several inches thick; by its physical characters it is evidently one of the last of the recurrent deposits of the black shale. 472 A and B are sections on the west side of the valley, while the section C runs off to the northeast along the gorge of Stony Brook, and traverses 160 feet of strata, the top sandstone C^6 reaching an altitude of 1,345 feet approximately.

472 A is an imperfect section directly west of the village, traversing about the same strata as those seen in B.

The sandstone in the midst of this section is apparently the same that is worked in the quarry at 472 B and met with again in the section C at C[3]. Above this sandstone no black shales have been seen. In section A it is several feet thick, massive, calcareous, of a gray color, weathering brownish gray, fine grained, and hard. It contains in the upper layers the perforations called *Fucoides verticalis* in the State reports.

The sandstone is followed by irregular layers of thin sandy shales and thicker olive shales, not fissile, but blocky in fracture and of rough surface, and in places nodular, the nodules about the size of hickory nuts and calcarceous; the shale is also slightly calcareous. A few fossils were found in these olive shales, but in a poor state of preservation.

The fauna determined is as follows:

Cardiola speciosa.
Lunulicardium levis, n. sp.
Goniatites complanatus.
G. bicostatus.
Lucina Wyomingensis, n. sp.
Lucina Varysburgia, n. sp.
Orthoceras (frag.).
Pleurotomaria (frag.), *(? P. capillaria)*.
Crinoid stems.

All rare, but the *Cardiola* and *Goniatites* are more common.

Quarry of the Tonawanda Valley and Cuba Railroad—472 B.

This quarry is west and about fifty feet above the station of the Tonawanda Valley and Cuba Railroad at Varysburg. The top of the ledge from which quarry stone is worked is 1,292 feet above tide.

The upper course is two feet thick, with a tendency to divide into two one foot courses. This is 472 B[1]. It is a light olive gray, massive sandstone, calcareous, and perforated in the upper part by numerous tubes of the so-called *Fucoides verticalis;* these are filled with the darker material similar to the overlying shales. It weathers to a cream olive or brownish gray, but has very little iron impurity and is a fine grained, firm sandstone.

B[1] lies upon a six inch mass of fine, blue, fissile, argillaceous shale, which separates it from the second two foot course of sandstone, which is a solid, compact, and even textured calcareous sandstone of light green gray color, like that above, except that the worm tubes, *Fucoides verticalis*, are wanting. Below this, separated by thin layers of soft shale, are two thin courses, respectively twenty and ten inches thick, forming the bottom of the quarry. There are no worm borings in these lower courses, but the petroleum odor is more apparent than in the upper sands.

The total thickness of this sandstone ledge is thus about seven feet, and it has furnished some very fine stone for railroad bridges and heavy masonry. In the shales forming the partings there are seen a few chips of fossil wood, but no other fossils were detected.

B^4.—Under the sandstone is about ten feet of a greenish, nodular, calcareous shale, irregular and with rough fracture, mainly argillaceous; the upper half is more nodular, the lower strata becoming more even and smoothly stratified. This is nearly barren of fossils, but in it were seen traces of a small *Cardium*, with prominent beak, and a small ?*Goniatites*. Below this is a fifteen inch course of sandstone like the quarry stone above, underlined by green gray, nodular shales, which run down into bluish gray, rough surfaced shales, and at about three feet from the base of the sandstone there is a few inches of fissile, finely laminated, black shale (B^5), with petroleum odor and *Sporangites*. Under this, as far as was examined, were alternations of argillaceous, bluish green shales, with the thin, arenaceous shales so common in the Upper Portage deposits. The former shales are distinctly calcareous, and a single small *Palæoneilo* was found about fifteen feet below the base of the quarry. This *Palæoneilo* is of the type of *P. brevis* and *P. Bedfordensis*, but of much smaller size. It agrees in shape and marking more closely with the Hamilton form *P. plana*, though but one-third the size. I have provisionally called it a variety of the latter species, with the varietal name *Varysburgia;* it is seen again in 472 C^1.

Stony Brook, Varysburg —472 C.

The first rocky exposure is approximately 1,185 feet above tide. Beginning from the base and running up it presents the following characters:

C^{00} is a tough, calcareous sandstone, seen just at the water's edge. It is greenish gray in color, but is not a pure sandstone, showing some admixture of the greenish shale. It is immediately followed by C^0, 6 inches to a foot of compact, black, bituminous shale, containing an occasional *Sporangites* and fragment of carbonized wood. Minute pyrite accretions are also seen, and an occasional worm boring perforating its lower layers from the green sandstone, C^{00}, below. The line of superposition is irregular, as if the surface of the sandstone material were broken up and disturbed during the deposition of the first part of the black shale. The green, sandy shale occurs in irregular lumps and layers, and the black shale itself, after it began to be deposited in thin, perfectly smooth layers, is seen, on a cross section, to be interlaminated with very thin sheets of the lighter shale.

C^1.—Above the black shale is, first, a foot of smooth surfaced, gray shale without fossils, followed by two inches of fine, soft, argillaceous shale, greenish gray in color, not very fissile, but breaking up in blocky flakes, with rough, uneven surface, and containing numerous fossils, and slightly calcareous—a frequent character of the fossil bearing shales

of the Portage group. It appears like a soft mud deposit, stirred up by worms or mollusca moving about on the bottom, though the material is identical with the fine, smooth, fissile, olive shales met with in the same series. Where this shale cleaves with a smooth, even surface it is extremely rare to find the least trace of a fossil.

The fauna of this shale (C^1) is as follows:

Cardiola speciosa (=*Glyptocardia speciosa* Hall, 1885).
Coleolus acicula.
Goniatites bicostatus?
Lunulicardium fragile.
Pleurotomaria, a fragment, ? *P. capillaria.*
Palæoneilo plana, variety *Varysburgia* H. S. W. (n. var.).
Orthoceras, a fragment of a small, slender form.
Leda diversa.

The first two species of this list are common; the *Goniatite* is represented by several fragments; the other forms are rare.

These fossiliferous shales are followed by a few feet of blue gray shales like those below, capped by two layers of hard, sandy shales occupying a foot and a half, the lower part wavy and perforated by the *Verticalis* worm borings, the upper part concretionary and greenish in color. Above this for some fifty feet, are alternations of the greenish, soft, argillaceous shales, and thin, darker bluish, more arenaceous layers, with an occasional thin, black streak, quite black near the bottom, but only recognized by a darkening of the ordinary bluish shale toward the top. An occasional *Cardiola speciosa*, but no other fossil, was detected in the mass.

This is terminated by a solid, compact, gray sandstone, C^2, two feet thick, darker than those above, but like them in having the upper part penetrated by the worm borings called *Fucoides verticalis.* The fillings are darker than the matrix and are apparently composed of the material of the overlying shale. This is C^2; it is calcareous and in general character is like the majority of the gray sandstones of all this region. They may well be denominated *Verticalis* sandstones and are generally light gray in color, rarely less than two feet in thickness, calcareous, and very generally give out a strong petroleum odor when freshly quarried, which they lose upon exposure to the atmosphere. The *Verticalis* borings are sometimes wanting, but the top layer of the mass will generally be found to contain these markings. The Portage sandstones of Portageville and the falls are a well known example of them when deposited in thick masses.

In the sandstone, 472 C^2, a single fossil of considerable importance was found. It consists of a fragment of a fish plate, an inch wide by an inch and a half long, thin on one edge, but tapering at one corner to a third of an inch in thickness. The surface markings consist of tubercles partly confluent and resemble the markings of the *Holoptychius giganteus* scale figured in Murchison's Silurian System. It

may be a fragment of the dorsal shield of some such fish as the *Aspidichthys* of the Huron shale, but the tubercles are not isolated, are closer together and more confluent than in Dr. Newberry's species of *Aspidichthys clavatus*. From the thickness of the fragment I infer that it belongs to a dermal plate, and refer it provisionally to *Aspidichthys clavatus* Newberry.

Above C^2 the sandy shales, in their alternation, predominate over the olive shales; they are more frequent, and stand out on the cliffs as stiff seams two to eight inches in thickness.

Nineteen feet above the top of C^2 is the base of a second *Verticalis* sandstone, C^3, eight feet thick, but not in a compact mass, being broken up by thin, shaly partings, though one solid layer two feet thick lies at the top. This is calcareous, as usual, and is impure by admixture of a little material of the green shales; also traces of iron are seen in the slight brownish tint of weathered surfaces. The ordinary nodular, olive shale underlies it, and this rests on the blue shales, which are becoming more common among the tougher, arenaceous deposits of these upper beds. In the bed of the creek a broken block of C^3, or something very similar, contains a large *Cladochonus*, with cups nearly two centimeters long, and on the same slab are the impressions of a *Cardiola speciosa* and a *Chonetes lepida*. This fragment shows no trace of lime, but this is not strange, as some of the sands by weathering seem to lose what little calcareous matter they may have contained. The light olive shale associated with C^3 is slightly calcareous, not fissile, but with blocky fracture and rough surface, approaching the character of the nodular shales. In it I found a specimen of what I first supposed to be *Cardiomorpha suborbicularis*, originally referred to *Ungulina*. Several specimens of this shell have been taken from various exposures of these olive shales of the Portage, presenting some features not referred to in the descriptions of the species. These are figured in Plate III, Figs. 13 and 14, and described below under the genus *Lucina* of Bruguière and referred to new species, *L. Wyomingensis* and *L. Varysburgia*. (See p. 44.)

The sandstone, C^3, is immediately followed by tough, wavy, arenaceous layers, running up, in a few feet, into blue shales, then green shales, and the peculiar nodular, olive shales of rarer occurrence at this position. These characters continue in irregular order for about twenty feet more, when a third *Verticalis* sandstone appears, C^4. This is very similar to C^3 in general characters and thickness. The upper part, particularly, shows the *Verticalis* markings. The nodular shales underlie this sandstone as they do the sandstones of lower position.

In the green nodular shales the following fauna appear:

Goniatites Patersoni.
Nucula corbuliformis, var., a small variety, in form and markings like *corbuliformis*, but about half the normal size.
Orthoceras pacator.
Lucina Varysburgia, n. sp. (?= *Ungulina suborbicularis* Hall).
Cladochonus, sp. Same as seen in the Eastern Portage.

DESCRIPTION OF TWO NEW LUCINAS.

Lucina Wyomingensis, n. sp. Plate III, Fig. 13.

Outline nearly circular, about 12^{mm} wide; hinge margin nearly straight, 10^{mm} long; umbone subcentral, small, extending slightly beyond the hinge margin. Shell evenly arched, the umbonal ridge subangular anteriorly near the beak, but rounded beyond. Surface with strong concentric ridges, no radiate striæ, except on the cardinal angles, where are several sharply defined, radiating striæ, stronger toward the margin and reaching under the beak; eight or nine of these ridges can be seen each side the beak, occupying the space of 4^{mm} from the cardinal angle, beyond which no traces of striæ can be seen. The concentric folds are about the size of the larger folds of *Lucina* (*Paracyclas*) *lirata*, which the shell resembles. From that species it differs in the more erect beak, in the radiating striæ at the cardinal angles, and in the absence of finer intermediate concentric striæ; the concentric folds are rounded, and not sharp as in *L. lirata*.

From the Portage shales at Varysburg (472 A).

Lucina Varysburgia, n. sp. Plate III, Fig. 14.

Outline of shell nearly circular, 17^{mm} long, 18^{mm} wide. It resembles in form the *Paracyclas Chemungensis* of Hall, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II, Plate XCV, Fig. 23, but still more the figure of *Ungulina*=*Cardiomorpha suborbicularis*, 1883=*Edmondia ? tenuistriata*, 1885, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II, Plate LXIII, Fig. 9. The surface is nearly smooth, slightly and evenly convex, except in the presence of a slight sulcus, separating a triangular portion of the anterior ? cardinal angle. The cardinal angles near the margin are marked by radiate striæ fainter and fewer than in *L. Wyomingensis*, but of the same character; four or five are visible on each side. There are faint concentric striæ visible near the margin of the shell; also very faint radiate lines.

In a second specimen, which is crushed, but appears to belong to the same species, there are stronger concentric folds near the front margin. The beaks are erect and nearly central, low, and scarcely extending beyond the hinge margin. Upon first examination I was inclined to refer this form to the species originally described as *Ungulina suborbicularis* by Hall in Geol. of N. Y., 4th dist., p. 243, Fig. 2, 1843. This was figured in plates and explanations of Lamellibranchiates, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II, Plate LXIII, Figs. 9, 10 (issued in 1883), under the name *Cardiomorpha suborbicularis*; but in the final volume (Vol. V, Pt. I, Lamell. II), published in 1885, the species is altogether discarded and the Figures 9 and 10 are referred to another genus, *Edmondia ?*, and described as a new species, *E. tenuistriata*, on page 393. (See also Am. Jour. Sci., 3d ser., Vol. XXXII, p. 192.) The original is said to come from the shales of the Chemung group near Elmira, instead

of Eighteen Mile Creek, Portage group, from which the original of *Ungulina suborbicularis* is recorded. So far as literature goes, we are left no means of distinguishing *Ungulina suborbicularis*, except the original brief description in the Geology of New York, first dist., 1843. The condition of the specimens is too imperfect to enable us to recognize such surface markings as are given on Fig. 10, Plate LXIII, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II. The specimens before us also differ from the *Ungulina* and from any described *Lucinas* of the Devonian in the radiating striæ on the cardinal angles.

This mass, 472 C^4, tends to be flaggy and break up into layers an inch or a few inches thick, and it is less easily separated at the top from the coarse shales that follow. A few feet above the solid part of this sandstone mass the shales are bluish and break up into irregular slabs, rough surfaced, and a few of the layers contain abundant specimens of the *Spirophyton cauda-galli*.

C^5.—The shales containing the *Spirophyton* are rather darker than the general color in this part of the section, of bluish green tint, and calcareous. Worm tracks are abundant, producing markings very similar to what are usually called *Fucoides graphica*, if not identical with them. These conditions continue upwards, varying somewhat, but with the general character of coarse, blue gray shales and thin, arenaceous layers occasionally containing numerous specimens of *Spirophyton*, till we reach the highest sandstone of the section, C^6.

C^6.—This is a thick ledge of solid sandstone about 8 feet in thickness at the thickest part exposed. It appears to be a lenticular mass, thinning out in two directions; the grain is a little coarser, mica specks are more numerous, and the weathering gives it a decidedly yellowish tint, from the presence of iron. It is not calcareous, so far as observed, nor were any traces of the *Verticalis* worm-borings seen, though they may appear in the top layers covered by soil.

This terminates the rock exposure of this ravine; the top of C^6 is approximately 1,345 feet above tide level, or 160 feet above the base, 472 C^{00}. This section shows us the general law of the appearance of the *Verticalis* sandstones in relation to the black shales. The sandstones first begin to appear soon after the last black shale; after a genuine *Verticalis* sandstone of two feet or more in thickness has appeared, no black shale is seen again. The sandstones appear in this section about twenty-five feet apart, becoming thicker above and farther separated from one other.

They certainly begin in the midst of the green shales of the Portage, with its characteristic fauna, and, as will be shown further on, continue after this fauna ceases; their order of appearance in thin shales is similar in each case: the nodular, green, calcareous shales precede the sands and the bluish and more arenaceous deposits follow. The greenish shales are evidently the mark of the older conditions and the bluish shale of the later, as the former are more frequent and characteristic below,

while the bluish shales and thin, flaggy, and often wave marked sands are characteristic in the higher part of the series.

In relation to other sections, the base of 472 C probably laps over the top of 468 D, the latter not reaching quite to C[3], but passes to the top of the recurrent black shales.

DESCRIPTION OF WORM TRACKS.

Arenicolites duplex, n. sp. Plate IV, Fig. 9.

In the green shales in the lower part of the Stony Creek section was found the single specimen which is figured in Plate IV, Figures 9*a* and 9*b*. This was lying horizontally in the rock and combines several interesting features. At the free end (upper in the figures) the specimen presents in each of the arms the characters so frequently met with in the New York Devonian, and when regular often spoken of as *Fucoides graphica*. When closely examined these are found to be not stems leaving their impression in the mud, but the fillings of grooves made in the surface of the mud and filled by repeated depositions of thin layers of mud in the groove. In the lower part of the figure will be seen the mode of joining of the two tube fillings, curving around in a regular arch, the arch being repeated a number of times at different places, but nowhere as strong as the side tubes. This character is repeated in the forms called *Spirophyton* (see particularly *Spirophyton velum* of the 16th Ann. Rep. Reg. Univ. N. Y., Plates LXXX, LXXXI, originally figured by Vanuxem in the Geol. N. Y., 3d dist., p. 177). I liken them to the vertical borings called by Salter *Arenicolites* and by various authors *Scolithus* and *Fucoides*, and consisting of tubular fillings more or less vertical in the rock.

I select the generic name *Arenicolites*, following Salter, who proposed to restrict this name (an adaptation of Binney's name *Arenicola*) to those worm borings connected by a loop or appearing in pairs and showing double openings (see Salter, Quart. Jour. Geol. Soc., London, Vol. XII, p. 248, 1856; Vol. XIII, p. 204, 1857).

The explanation of the formation of such dissimilar markings by the same organism is easily understood by watching the common earth worm penetrating deep into the soil, out of sight, and after a rain storm coming to the surface, stretching out its length, and by sudden retraction drawing sticks and leaves and loose fragments into the mouth of its tube.

I can imagine how a worm with slightly modified habit might bore its tube in the mud and with its posterior part anchored in the hole throw its body out, curving it to one side, and thus form a loop, which, by sudden retraction, would leave the kind of mark seen in the *Spirophyton*. And it is easy to conceive how the same kind of worm which left its mark on the surface might perforate vertically in the mud, as we find worms doing today.

I call this specimen *Arenicolites duplex*, but imagine the maker of the track was nearly related to the maker of the markings called *Spirophyton*, and that the vertical borings so common in the sandstones of the Upper Devonian were made by the same kind of animal, though many species or even genera may have been engaged in forming these various worm tracks.

Danbree quarry, Bennington, Wyoming County, N. Y.—473 A.

This quarry is situated on the hillside above the railroad, westward, between Sierk's and Earl stations on the Tonawanda Valley and Cuba Railroad, 3½ miles south of Attica. According to estimates based upon the grade of the railroad, the top of the quarry is approximately 1,465 feet above tide. The rock outcrop was first struck about 40 feet below the top of the quarry and measured up; a few outcrops below this point furnished specimens, but their altitude was not measured—only their order.

A^1, altitude 1,426 feet, a calcareous sandstone averaging a foot in thickness, gray olive, with *Verticalis*, followed above by seven and one-half feet bluish and nodular shale.

A^2, altitude 1,433½ feet, two feet of massive, gray, calcareous sandstone, weathering brownish, with *Verticalis*, followed by six feet of bluish and nodular, olive shales, then an 11 inch sandstone seam, then five feet and a half of shales and a six inch seam of sand, then nine feet shales, in which *Spirophyton* and the so-called *Fucoides graphica* appear, bringing us to the base of the main quarry stone. The shales immediately under it, bearing *Spirophyton*, are greenish gray, calcareous, and rather soft, breaking with rough surface.

The quarry stone, A^3, is light gray, calcareous, and very uniform and massive; in the quarry it is composed of a ten inch course at the bottom, then what appears to be a solid course of seventy-one inches (but in quarrying there are a few lines of cleavage), on top of all a fourteen inch course, in the upper part of which *Verticalis* tubes are abundant. Above the quarry about twenty feet are exposed of blue gray shales, and towards the top a few thin sandstone layers. The fifty feet below A^1 is composed of bluish and gray shales, with hard, flaggy, arenaceous layers, and below, at about 1,375 feet to 1,380 feet, is a layer of nearly pure limestone, outcropping in a ledge of several inches thickness, but mostly covered, a few feet above which is a stratum of black, fissile shale with *Sporangites*.

The next exposure examined below this is at Sierk's station, where black shales appear both above and below the railroad, and they continue upward, appearing in considerable thickness, certainly fifty feet above the railroad. There is a thickness of 275 feet above the lowest black shales at Sierk's before they entirely cease. Taking the upper beds of the black shales as criteria, there would be evidence of very little, if any, dip from Attica (468 D) to Sierk's (473 B), and even at Varysburg

(472) they reach above 1,200 feet in their recurrences. At Java, eight miles farther south and three miles west of Varysburg, the black shales appear in thick masses considerably above 1,200 feet altitude, and underlying the fine, thick sandstone, above 1,300 feet altitude, is a layer of black shale with *Sporangites* and a strong smell of petroleum. This quarry sand of 473 A^3, if we regard it as equivalent to C^6 of 472, which is also underlaid by a shale bearing *Spirophyton*, dips to the south at about fifty feet to the mile.

If now we compare this with the Java section (475) we find that the first strong sandstone stratum (475 A^6) actually underlaid by a black shale lies over seventy feet higher than the first sandstone of Varysburg (472 C^2). And across the county, eastward, the highest streaks of black shale do not reach much above 1,050 feet altitude, at Portage Falls, but the sands beginning at the upper falls occur in masses scores of feet thick before an altitude of 1,300 feet is reached.

These facts tend to show that in this region the rocks show as great differences on passing from west to east in line of the supposed strike as they do from north to south in line of the dip. The relation stratigraphically between the black shales and the *Verticalis* sandstones is not uniform, even within the limits of a single county. There is nothing to show that there is any considerable folding of the general rock masses to account for these differences.

The only feasible explanation seems to be that the *Verticalis* sandstone is stratigraphically connected with the cessation of the black shales, and that the black shales run up higher in the midst of the Portage green shales, as we trace them upward, in a western and southwestern direction.

This points to a possible explanation of the apparently much higher position of black shales in Ohio, in relation both to the lower deposits and to the subcoal conglomerates, upon which point further light must be thrown by the study of the sections farther west as we approach and enter Ohio.

Sierk's Station (T., V. & C. R. R.), Wyoming County, N. Y.—473 B.

The railroad grade at this station is approximately 1,100 feet above tide level. The profile of the road, which I was permitted to consult through the kindness of Mr. J. V. D. Loomis, general freight and passenger agent at Attica, gives the original survey of the road, but I was not able from the maps at hand to locate precisely the present station at Sierk's. Taking the altitude of the grade at Attica as 998 feet and at Earl's as 1,178 feet, I estimated that Sierk's crossing is not far either way from 1,100 feet. About fifteen feet below the railroad, the lowest exposure is a massive, black shale. The black shale is the principal rock, though for twenty-five or thirty feet upward blue shales alternate with it.

The black shales, 473 B^1, resemble very closely the second recurrence of black shale at Attica, as seen in 468 C^3 or 468 E. It is fissile, with some arenaceous particles, weathers with brown iron stain, has petroleum odor in the freshly opened strata, and contains *Sporangites* and *Styliola*. This station is three miles a little west of south from station 468 C and E, and the black shales at the bottom are nearly on a level with the lower black shales of 468 C^3 and E. The section 468 D contains no such massive black shale and begins about a hundred feet higher. It is evident, therefore, in these three miles going southward, either that the black shales increase in thickness upward or that there is very slight dip of the rocks, not over fifty feet in the three miles. This is further corroboration of the view expressed in the discussion of 473 A. (See p. 47.)

Ravine east of Java Village, Wyoming County, N. Y.—475 A.

This station is nine miles north of Arcade (474), about eight miles southwest of Varysburg (472), and two or three miles west of the direct line from Attica (468) to Arcade (474). In direct line it is about twenty miles west and a little north of Portageville, lying about six miles north of the latitude of the falls. The altitude is estimated from a series of levelings run from the railroad at Java Center, 475 A^6, showing the top of this sandstone to be approximately 1,315 feet above tide level.

This sandstone (A^6) is a ledge of about two feet workable sandstone, as seen in the old Macoon quarry. It is a solid gray sandstone, the thickest course averaging a foot in thickness and calcareous. Two brachiopods were detected in it, one a minute shell, like a *Cyrtina*, but too indistinct to be clearly defined, the other a large *Spirifera*, over an inch wide, the best specimen crushed, but showing the ventral sinus with plications about the same size as those on the main part of the shell. This is plainly of the *S. disjuncta* type, but it would be difficult to determine it certainly. What is preserved of it looks like a *Spirifera disjuncta* with extended hinge and moderate area. With these were found fragments of crinoid stems. This is the lowest point at which traces of the Chemung fauna have been seen along this meridian, and it is of particular interest on account of the prominent stratum of black shales underlying it by only a few inches bearing a few *Sporangites* and, when freshly broken, giving out a strong petroleum odor. The sandstone has the same odor when freshly broken. It is followed above by soft, argillaceous shales, much as in the McGee quarry at Arcade (474 A), and lies upon a few inches of similar shales (475 A 5^a). The black shale (A^5) is massive, six to eight inches thick, a decided black, but not the brown black of the lower representatives. Below the black shale, for some fifty feet, the rock is the ordinary alternation of bluish shales and thin sandstones, the latter often wavy and flaggy, as seen in the Upper Portage series. At this point is a heavy sandstone ledge which could

not be reached, forming a fall of some twenty or thirty feet. Under this ledge the cliff is composed of soft green shales, with frequent bands of black, increasing in thickness toward the bottom, with an occasional seam of the green, nodular shales such as those seen at Varysburg and other places. At about thirty-five feet below the brink of the fall the green shales were examined and furnished numerous small fossils (A^3).

A^3.—This is an olive gray shale, soft, argillaceous, calcareous, and nodular in places. The fossils determined are—

Cardiola speciosa, numerous.
Coleolus acicula, rare.
Palæoneilo (small).
Goniatites (minute).

Below this are a few feet of shale, then another strong black streak, another mass of olive shale, and a thick mass, six feet or more in thickness, of brown black shale (A^2), with *Sporangites* and strong petroleum odor; under this is seen, in the bed of the stream in the village, a gray sandstone, A^1, very similar to the bed at the base of 472 C, calcareous, with petroleum smell and traces of crinoid stems, but no other fossils were detected. This base is not far from 100 feet below A^6 and at an altitude a little over 1,200 feet above tide.

It will be seen from this description that the black shales continue to recur frequently up to, say, 1,250 feet altitude, and are represented by a stratum of six inches average at 1,300 feet. If we compare this section with that at Portage Falls, we appear to be perfectly justified in regarding it as equivalent to the rocks underlying the upper falls, that is, entirely below the genuine Portage sandstones. This conclusion appears to be supported by the general nature of the strata as well as by their stratigraphic order. Though lying at a considerably higher altitude than the Portage Falls sandstones, the facts of the apparent running out of the black shales and of the absence of any thick, massive sandstone up to the top forbid co-ordinating it with lower strata of the Portage section, where the black shales are frequent, or with strata above the Portage sandstones, where the black shales cease to appear. But the occurrence of the *Spirifera*, of decidedly Chemung type, shows plainly that when the sandstone 475 A^6 was deposited the Chemung fauna could not have been geographically far distant and was in full force somewhere.

CHAPTER III.

THE PORTAGE SANDSTONES AND THE FAUNAS OF THE CHEMUNG GROUP.

As we approach the southern boundary of Wyoming County the Portage sandstones form the principal rock outcrops and slight traces of the Chemung fauna begin to appear. Crossing into Allegany County, the Chemung rocks are the only rocks on the hills, though in the northeast corner of the county the lower rocks are still Portage, and in the southern part of the county the higher hills are capped by conglomerates — the flat pebble conglomerate in several places, but the Olean conglomerate at Little Genesee.

The group of rocks included in this chapter are represented at the following stations:

Wyoming County: Arcade, 474; Allegany County: Rushford, 476; Cuba, 477; Black Creek, 478; Rockville, 479; Belfast, 480; Caneadea, 481. Here is also included the section at Portage Falls, 482.

Portageville, Livingston County, N. Y.—482.

The Portage sandstones, as seen in section 482, were early recognized as an important member of the Upper Devonian series in Western New York.

Prof. James Hall, in the first reports of the State survey, described them as exposed at Portage Falls and regarded them as characterizing the close of the Portage formation and separating it from the Chemung group above.

"The upper part of the Portage group," he says (Geol. of N. Y., 4th dist., 1843, p. 484), "consists of a mass of slightly argillaceous sandstone, compact and fine grained, from 150 to 200 feet thick, in some places containing pyrites which stain the rock an iron rust color. This rock is quarried in blocks from 1 to 3 feet thick, and of any required thickness and any required size; it breaks easily when first quarried and will scarcely stand the vicissitudes of climate."

These Upper Portage sandstones are regarded in the early reports as characteristic of the termination of the true Portage series in this part of the State. The presence of the "vertical fucoids" in this heavy sandstone is another character marking the terminal mass. (See op. cit., p. 248.) But it did not escape the acute observation of the New York State geologist that these distinctions between groups of continuous sedimentary deposits must be, from the nature of things, provisional and in great measure local.

The re-examination which I have made of these deposits brings to light another fact, viz, that the conditions associated with and marked by the deposition of these gray sandstones — which were generally

slightly calcareous, and when fresh distinctly bituminous to the smell and showing almost universally the presence of the "vertical fucoids" at their upper junction with the shales—were the conditions regularly following the termination of the black shales. Although in some cases there may have been thin deposits of the sandstones between black shales, it is not until after the cessation of the Devonian black shales that these massive gray sandstones appear in full force. When they appear in the midst of the Portage shales containing the Portage fauna they are, so far as observed, barren. The lower down in these Portage shales we find them, the darker, the more finely grained, and the more impure are they by admixture of argillaceous matter; and after reaching the Chemung faunas the sandstones are of lighter color in the western areas of the State and of purer sand and coarser grain in proportion to the lateness of the beds in the general Chemung series.

The altitude of these sandstone deposits at Portage Falls is between 1,100 and 1,200 feet above the sea. The New York, Lake Erie and Western Railroad bridge passes over the gorge at an elevation of 1,314 feet above tide level. The top of the quarry sandstone is about 100 feet below the bridge, or say 1,200 feet altitude. Good quarry stones are found at the level of the old canal road, which is at an altitude of 1,125 feet to 1,130 feet along these cliffs, and, even considerably lower, thick courses of the sandstone are seen, but there the shales prevail.

The prevailing color is a pure light gray of slightly olive tint, about the same shade as the Rockville stone, somewhat lighter than the upper stone of Wyoming County, north, and darker than the upper Rushford stone. The Cuba stone has a decidedly lighter shade and a more open and coarser texture. No fossils have been seen in these typical Portage sandstones. The black shales are recognized nearly up to the upper fall, which may be regarded as the first genuine stratum of the sandstone, but no black shales have been detected by me in this section above the strong stratum of 3 or 4 feet thickness of this sandstone. Interstratified with the black shales below are seen the regular gray and olive shales of the Portage group, containing the Portage fauna, *Cardiola speciosa*, *Goniatites complanatus*, *Palæoneilo plana*, var.

The lighter colored bands have the peculiar nodular structure frequently found in the Portage formation. The highest band of black shale I saw in the ravine contained a few well defined specimens of *Sporangites*. The petroleum odor associated with all these gray sandstones following the black shales of the Portage group gives strong reason for the opinion that they are the sandstones which occur farther south, and there, covered by thick masses of overlying strata, contain the oils reached by drilling.

McGee Quarry, Arcade, Wyoming County, N. Y.—474 A.

This quarry is on the hillside south of Arcade, about three-fourths of a mile from the center of the town and east of the cemetery. The

top of the main quarry stone ledge, A^2, is approximately 1,600 feet above tide. This altitude is based upon railroad grade at Arcade and measurement from that by aneroid barometer. Both Locke level and barometer have been used in obtaining levels in this survey, and while I regard them as approximately correct for purposes of geological comparisons of levels of the respective rock exposures, they may often vary several feet from the absolute altitude above sea level.[1]

The region north of Arcade for several miles is high rolling land, with heavy soil, and directly north no rock exposures are met with till passing beyond the summit in Java township.

The quarry 474 A is composed of the following courses from below upward:

A^0.—Three foot sandstone, fine working and soft when first quarried, running below the base of the quarry as now worked. This is followed by

A^1.—Six inches of soft, blue, argillaceous shale, weathering quickly into a tough clay;

A^2 is a 16 inch sandstone, compact; and

A^3 is six or seven inches of thin parting of soft blue shale; then six inches irregular sand; then slate with sandstone veins and masses, or what may be called a clay breccia, appearing as if it were a clay bottom which had assumed some solidity when it was violently disturbed by the rapid insertion of the sand, often with mica, so that the clay nodules, like broken lumps, are in the lower layer of the sand and all mingled with it. This peculiar condition of rocks has been observed in several localities, associated with the incoming of the conditions in which the Chemung fauna appears. A similar rock appears farther east, at the base of the Catskill rocks.

A^4.—Then follows a 13 inch sandstone, compact and calcareous; at the top of this sandstone, separating it from the course lying above, is another layer of the peculiar claystone conglomerate; then a 20 inch course of sandstone; then a 6 inch course.

A^5.—The whole is terminated by an uneven mass of the clay pebbles, embedded here in a calcareous mass of purple color, with some sand,

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[1] Though I have employed an aneroid considerably in the past few years—using a Troughton & Simms registered, compensated for temperature—so far as the machinery is concerned, I am convinced, after trying several instruments, that the more delicate the instrument the more certain it is to be affected by the atmospheric fluctuations and to record only approximately altitudes which require more than ten minutes in passing between them, even under like conditions of temperature; and in the field, without a stationary barometer for comparison, altitudes determined by a single reading cannot be considered as more than approximately correct when pressure of atmosphere is the basis of the determination.

All the altitudes given in this report, unless particularly stated as railroad grade, must be regarded as subject to such correction. The error in any case, however, I do not believe is enough to seriously affect the geological considerations for which the measurements are made, as in each case the diurnal fluctuations and the changes in temperature have been taken into account, as well as the general atmospheric conditions, in making up the estimated altitude.

but principally calcareous matter composed of fragments of shells and bryozoa and crinoid stems, very much pulverized, but showing their source in the occasional fragments, large enough to examine, and terminating above in soft, argillaceous shales.

In this quarry the sandstones are of a gray color, weathering brownish or chocolate, then bleaching upon long exposure to a purer gray, and some fresh specimens gave a strong petroleum odor. No *Verticalis* borings were detected. Even weathered samples are calcareous, but fresh, light gray samples are highly calcareous, and the purple layers, such as terminate A^4, are more calcite than sand.

The layers of soft, green, argillaceous shale, whether in layers or in pebble-like nodules embedded in the sandstone or limestone, are not calcareous. There appear, also, at these intervals, between compact sandstone and thick strata of green shale, thin, vein-like streaks, very uneven but in the main horizontal, stratified with the shales, of nearly pure quartz sandstone, varying from a sixteenth of an inch to an inch or so in thickness. They are often pure white or very light gray, with not a trace of calcite. There are also frequent partings of grains of mica, forming very evenly laminated, flaggy layers, from a quarter of an inch to several inches thick.

In the arenaceous limestone layers there are traces of several fossils which are decidedly distinct from the Portage fauna. The limestone has a purplish tint and is distinctly crystalline in some parts. It appears to weather quickly by solution of the calcite, leaving a greenish brown, loose, crumbling sandstone. Among the pulverized fossils several generic characters were identified (but they are too fragmentary for the determination of specific relations): little bryozoan stems like *Ceriopora*, numerous small sections of crinoid stems, pieces of a brachiopod with the structure of *Orthis*, a small *Spirifera* with plications in the ventral fold, another portion of the beak of a *Spirifera*, which may be the same species, the surface characters not visible. From the fragments obtained the *Spirifera* appears to be of the *S. Archiaci* type of *S. disjuncta*, near *S. Whitneyi* Hall or *S. Orestes* Hall & Whitfield, from the Rockford beds of Iowa. Although it is not possible to strictly identify the species, it is important to note that it is a representative of the group of spirifers so common in the Chemung group. In some parts of this strange deposit are found numerous bivalve crustacea, *Estheria* and *Leperditia*, and *Entomis?*, the latter of a green color or filled with green phosphatic? mud. In section 475 the sandstone, 475 A^6, has a *Spirifera* similar to those just mentioned.

Although in both cases we see only slight traces of the fauna, I feel confident that what we do have is not the disintegrated material of an earlier age, but signifies the presence, at no great distance geographically, of the fauna which we know immediately followed the close of the Portage while these deposits were being made. The nature of the deposit and its associations are very similar to the calcareous stratum at High Point, Naples, Ontario County, in which a peculiar fauna for New York rocks was discovered, an account of which is given in Am. Jour.

of Sc., 3 d ser., p. Vol. XXV, pp. 97–104, 1883. There is nothing in the fragments found in stations 474 A and 475 A to prevent them from belonging to the same fauna and the probability is strong that they are from a common source. Further search should be made for this interesting forerunner of the Chemung fauna of New York.

Although the precise equivalency may not be determinable between this particular limestone deposit and any other series of deposits in which this fauna does not appear, it is a very suggestive fact that here for the third and fourth times traces of the Iowa Devonian fauna occur in New York deposits just at the point of transition from the Portage fauna, which seems to be peculiar to the east, to the Chemung fauna, which occupied the interval between it and the lowest coal formations.

Rushford, Allegany County, N. Y.—476.

The altitude of Rushford at the railroad station I estimated by aneroid readings running from Attica and to Cuba to be nearly 1,500 feet. These were long runs, but as they were severe tests upon the accuracy of this kind of estimate of altitude it was gratifying to learn later, through Mr. W. E. Wormelsdorf, the engineer of the railroad, that the measured altitude of Rushford station was 1,504 feet above tide. By aneroid estimates the deposits 476 G^0 are 1,350 feet or less, 481 A is about 1,600 feet in altitude, 481 B near 1,700, and 476 A is not far from 1,770 feet above tide.

The dip along Caneadea Creek is slight; near A it is perceptibly northward, but nearly level elsewhere, and it is probable that here is the southern rise of the gentle undulations in the rocks which produce but slight variation in the general southerly dip of the rocks in this part of the State. The dip is rarely more than fifty feet per mile and except in very limited areas rarely less than fifteen feet per mile southwestward.

The section 476 A is a ledge exposed alongside the railroad near the bridge, No. 57, between two and one-half and three miles north of Rushford.

A^1.— At the top are exposed six feet or so of soft, argillaceous shales which weather to an olive green; no fossils discovered; mica partings are seen, and by continuous deposition of the mica occasionally sheets an eighth of an inch thick separate the soft shales.

A^2.— Under the shales are about six feet of sandstone and mixed sand and clay. The sandstone at top is rather coarse, of loose texture, with occasional mica grains, with some iron stain and occasionally ironstone nodules, not calcareous, weathering brown, dark brown, to almost chocolate black. The sandstone rests on a kind of mixture of sandstone and clay nodules, with large roundish masses of micaceous limestone or concretions of dark greenish gray, with much mica and fragments of wood fossilized. These calcareous masses have the petroleum odor common to many other similar masses. Where they are in contact with the shales fossils appear.

A^3 is a second shale underlying the mass A^2; it is a bluish, fine, mud shale, not so evenly bedded as A^1, but breaking with conchoidal fracture

when not weathered; this is veined with horizontal streaks of almost pure silicious sand, very light gray, with rough surface, often showing worm tracks. In the midst of the shale is an uneven mass of sandstone similar to that above, varying from eight to ten inches in thickness, and below are shales similar to those at the top. In a part of the exposure the color of the sandstone of A[1] at the juncture with the clay nodules (whether from weathering or not is not apparent) is a decidedly brownish red, the red of the Catskill rocks farther east, and the sandstone is slightly calcareous. It contains a unique fauna, though mingled with some Chemung types.

Fauna of the Centronella Red Band.—476 A·.

Of the fossils the most abundant form is a small terebratuloid shell, in size and general form most closely resembling *Centronella Julia* Winchell, of the Marshall sandstones. Next to this in abundance is a large, winged form of *Spirifera disjuncta.*

There are also—

Rhynchonella ? camerifera Winchell.
Productella Shumardiana, var.
Pleurotomaria, sp.
Rhynchonella contracta, var. (See Pl. 54 A, Figs. 50, 51, and pp. 417, 418, Geol. Surv. of N. Y., Pal., Vol. IV, Pt. I. The specimens of this station resemble the finer plicated forms of Rockford, Iowa, which were referred to *R. contracta*, var., and in a note were said to resemble young of *R. eximia* Hall.)
Nucula, n. sp., marked like a *N. lamellata*, but in outline approaching a *Grammysia Hannibalensis* (such as Meek gave in Pl. XVI, Fig. 5c, Geol. Surv. of Ohio, Vol. II, Pal.).
Nucula, n. sp., gibbous, quadrate, beak nearly central.
Cytherodon (*Schizodus*) *pauper ?*
Crania, sp.
Ambocœlia umbonata, var. *recta.*
Naticopsis ? sp., an allied form, new.
An incrusting *Bryozoan*—fragments.
Crinoid stem fragment.

476 B is a little outcrop of six feet, about thirty feet below 476 A. It is mainly thin layers of a very tough sandstone interstratified with softer shales. The sandstone is light colored, not calcareous; in one stratum the sandstone is very calcareous and appears to be a concretionary layer, not in balls, but nearly continuous.

B[1].—The sandstone contains several fossils; the first two species in the list are abundant.

Leiorhynchus mesocostalis, varying to *L. sinuatus.*
Ambocœlia umbonata.
Rhynchonella contracta, var.
Productella speciosa to *P. hirsuta.*
Spirifera mesocostalis, second and first varieties with median septum.

Streptorhynchus ? (small).
Orthis impressa ? large (faint).

B². — In a softer piece of shale from this horizon a *Spirifera disjuncta* was seen.

B³. — The calcareous streak contains *Ambocœlia* and traces of the *Streptorhynchus.*

The form and variation of the species of the sandstone B¹ are very similar to the species met with several hundred feet lower in a similar stratum in the shales at 476 G.

The outcrop 476 C is near bridge No. 59 and may be fifty feet lower than A. The principal stratum, C¹, is a strong, massive sandstone of six feet thickness at the bottom of the exposure, with soft argillaceous shales above for fifteen or twenty feet, interrupted by an irregular stratum (C²) of sandstone, averaging about a foot in thickness, in the midst of arenaceous shales, and in places becoming coarse sand of loose texture, weathering yellow upon exposure. At one part of the exposure the sandstone is very coarse, more like a fine conglomerate, with pebbles as large as an eighth of an inch in diameter and of flattened form, resembling in general character of the mass the lowest conglomerate or flat pebble conglomerate, as seen at 484 D and other places. This contains fossils, as will be seen beyond. C³, a shaly mass underlying this seam, contains also fossils of a decidedly Chemung type. This is strongly calcareous in places.

A calcareous slab from the bed of the creek appears to be from the same stratum, and its fauna will be given under 476 Bˣ, as it contains in fine state of preservation several species not found in the exposure in place.

On going down to the village thicker masses of conglomerate were found in the fences. This conglomerate, in the character of the gravel composing it and the fossils contained, appears to be identical with 476 C² in its coarser parts, and it is reasonable to infer that the conglomerate in the fences, with Chemung fossils and appearing there in slabs of several inches thickness, is from the same horizon as 476 C² or was deposited at a recurrence of the same conditions higher up; 476 A approaches very closely to the same conditions. In the latter, coarse, loose sand is seen, with a few pebbles, but no mass of gravelly sand or fine conglomerate.

476 C¹ is a fine, massive sandstone, in thick courses, without shales, of 6 feet thickness. The bottom courses are stained brown upon weathering and show mica grains conspicuously through the mass. A single fossil was found in this part of the sandstone, a dorsal valve of a large *Productella,* which may be defined as a large quadrate *P. lachrymosa,* moderately gibbous for a dorsal valve and showing clear indications of the radiating wrinkles which are more prominent in carboniferous species. The upper part of the sandstone is in a course of some 2 feet thickness as it appears in the ledge, massive, a pure gray, of uniform texture, with strong petroleum odor upon fracture, which the specimens

have not lost after six months in a dry room. There is only a faint trace of calcareous matter in these sands and the upper courses show only a slight yellowish tint of gray upon weathering.

Above the sandstone C¹ are soft shales (C²), tending toward a green color at first and strongly iron stained on weathering; on passing upward a few feet the shales become sandy (C³) and in places calcareous. The fauna appears to be the same for both and the lithological characters seem to vary locally in the relative prominence of the shales, sandy shales, or calcareous layers.

C³ contains the following fauna:

Spirifera mesocostalis (common), var. 2 and 3, with high area and strong median septum.
Athyris Angelica, several specimens, but not common.
Spirifera disjuncta, var. like *S. Whitneyi*.
Rhynchonella contracta, var. (small) common.
Productella hirsuta?, rare.
Streptorhynchus Chemungensis, several.
Centronella Julia, rare.
Mytilarca Chemungensis, one specimen.

A fine slab filled with fossils was found in the bed of the creek between C and B, and marked Bˣ. The fauna of 476 Bˣ, as well as the character of the rock, leads me to regard it as belonging to the same horizon as 476 C³. It is more fossiliferous and is a calcareous mass which has in all probability fallen down from the cliff at some point the continuation of 476 C³.

The species identified are:

Streptorhynchus Chemungensis, large, gibbous, of the quadrate form, with mucronate ears.
Spirifera disjuncta, the variety with high area and quadrate form.
Spirifera? Whitneyi, a single specimen presenting some of the characteristics of this Iowa form, but comparison of many forms leads me to think this but an extreme form of the *S. disjuncta* type.
Rhynchonella contracta, a small variety, resembling var. *saxatilis* Hall, Geol. N. Y., Pal., Vol. IV, Pt. I, p. 417, Pl. 54 A; also another variety very similar to Fig. 23, Pl. 55, but not belonging to the species *R. duplicata*, to which that figure is referred.
Productella costatula, with concentric wrinkles.
Athyris Angelica.
Orthis Michelini.
Chonetes scitula.
Centronella Julia.
Chætetes, sp.
Productella onusta.

476 C² is an outcrop of sandstone south of the exposure of C¹ and somewhat higher. I was not able to trace its exact equivalent in the

cliff above C^1 and conclude that the character of the seam rapidly changes. At C^2 it is not over a foot thick, not massive, but is a coarse, sandy layer, tending to pebbly conglomerate in places, weathering yellow, and is in the midst of the same soft, rough shales which lie above C^2.

The fossils are *Streptorhynchus Chemungensis* (large), *Rhynchonella contracta*, *Spirifera mesocostalis*, and some crinoid fragments. Markings, like those called *Fucoides graphica*, are conspicuous on the surface next the shales. The sandstone is hard and very compact in some parts; in other places it suddenly becomes coarse and loosely agglutinated, and contains pebbles an eighth of an inch in size, forming a fine gravel conglomerate.

476 C is a coarse sandstone forming a stratum above C^3 and is probably the continuation of C^2. It is a loose grained, coarse sandstone, weathering yellow, not massive, but apparently a local bed. It contains —

Spirifera mesocostalis, second and third vars., with strong median septum and moderately high area.
Productella lachrymosa.
Rhynchonella contracta, varying to the form called *R. suborbicularis.*
Orthis impressa, large, broad form (frag.).
Orthis (*Michelini* or *Vanuxemi*), small.
Centronella Julia.
Rhynchonella contracta (small var.).
Bellerophon mæra ? (internal casts).
Orthoceras Demus ?

C^4.—Other slabs of sandstone were found loose in the creek below with a similar fauna. In one hard silicious layer the following association of species was met:

Leiorhynchus of the *L. sinuatus* and *L. multicosta* types.
Productella, resembling *P. hirsuta*, but with strongly wrinkled margins.
Ambocœlia umbonata.
Spirifera mesocostalis, second var. with median septum.

These sandstones (C^2, C, and C^4) are not calcareous, but are more purely silicious than the ordinary sandy layers of this neighborhood. The loose conglomerate masses met with in the fences between 476 A and Rushford are composed of fine, silicious pebbles, often dark in color, but after weathering coated with a dark brown covering of iron stain. The pebbles are of the flat form met with in the lower conglomerates farther south, and the masses appear to be at best only a few inches thick, grading at their upper or lower surfaces into coarse sandstone.

The following species were found in these fragments:

Spirifera disjuncta.
Spirifera mesocostalis, with median septum, the small and the coarse type both represented.

Euomphalus, sp.? This is represented by only a fragment, but it has the character of this genus so far as it goes.

In these more northern exhibitions of the flat pebble and fine, polished gravel conglomerate the fossils associated leave no doubt as to their general position in the series. The presence of *Spirifera mesocostalis* with *Spirifera disjuncta* shows us that this conglomerate was not restricted to the closing stage of the life history of the Chemung faunas. In middle and southern Allegany County *S. mesocostalis* had been absent from the faunas a long time before the laying down of the typical deposits of the flat pebble conglomerate occurred, as at Wolf Creek and Portville. The period of the deposit of the Olean (the Portville) conglomerate was doubtless of long continuance, a period of violent oscillation, of rapid erosion, and of rapid spreading out of the coarse sediments. It put an end to the marine conditions for all this eastern area and closed the Devonian age. But my study of the section herein discussed reveals the general law that the faunas of the Upper Devonian in this area maintained their integrity longer the farther distant they were from the center of origin of the sediments, which must have been somewhere in the region of the Appalachian axis, and also that the coarser shore deposits, worn pebbles and gravel, were occasionally carried out and spread over the bottom during a comparatively early stage of the Upper Devonian faunas.

Interpreting this for Western and Central Pennsylvania I should expect there to find greater thickness and more numerous deposits of coarse sand and worn pebbles below the Olean conglomerate, extending far down into the Chemung period, as marked by the life; but I should expect the fossils to be rare after the appearance of the red and micaceous green shales, and the few that did appear should represent earlier stages of the faunas than those appearing in like lithological conditions in Western New York.

Caneadea Creek, below East Rushford.—476 G.

This section continues from 481 C upward. The shales at the base G^0 are more bluish than lower down, but are fissile and weather much in the same way. They contain more fossils and a few more species, but they are evidently of the same fauna. The streaks of hard, nearly white, silicious material are more frequent, and calcite appears in thin, greenish white, argillaceous layers. Mica appears occasionally, peppering the surfaces of some of the thin shales.

476 G^0 contains the following species:

Leiorhynchus mesocostalis, abundant in layers.
Leiorhynchus multicosta (or *L. sinuata*), var.
Orthis impressa, large, wide form, frequent.
Spirifera mesocostalis, second var., mucronated, rare.
Ambocœlia umbonata Hall, var.

Rhynchonella Stephani, var. approaching *R. Saffordi* var.
Athyris Angelica.
Worm tracks.
Productella lachrymosa, var. *stigmata.*

The *Leiorhynchus* is more common where the shales and sandy layers meet.

In the higher layers of the shale, where the sandy character becomes predominant (G^1), there is a *Rhynchonella* difficult to distinguish from the more regular forms of the *Leiorhynchus* occurring below. One of them is distinctly the *Rhynchonella contracta* of Hall (Pl. 55 A, Fig. 30, Pal. N. Y., Vol. IV, Part I). Others are irregular in the plications, more like *Leiorhynchus multicosta* Hall, and are possibly what Professor Hall has called *L. sinuata.*

For the first thirty feet above, the thin shales (G^2) and sandstones prevail, the sands in the upper part appearing as thick as six inches. At thirty-five feet a strong seam of sandstone (G^3) of three or four feet thickness appears, with some thin shale partings, so that the mass cleaves upon weathering into layers six to ten inches thick. In some of the exposures the sandstone is broken into thin, flag-like slates by thin layers of pinkish mica. Higher the fissile shales appear, but the fossils are not seen, and the arenaceous layers are more frequent and thicker than below. About ninety feet above G^3 appears a second massive sandstone (476 G^4). This forms the top of the cliff. Although I could reach its base I could not get at the top of it, which was covered by loose talus from the shales still higher. It appears to be from six to eight feet thick. For eighteen inches or two feet at the base it is solid, massive, of a gray color, weathering to a slight brown or chocolate tint, and of loose texture; above the rock is more firm and gritty, but no specimens were found to be calcareous. This is probably the rock referred to in the Report on Geology of the Fourth District of New York, p. 485, as extensively used for grindstones and quarried. It is the only exposure seen between Caneadea and Rushford likely to furnish material fit for such a purpose.

Just under G^4 *Rhynchonella contracta*, *Spirifera mesocostalis*, a small *Palæoneilo*, and stems of plants (or worm tracks?) were found in arenaceous strata; in more shaly strata the *Leiorhynchus*, varying as below from *L. multicosta* to *L. mesocostalis*, was seen. The clay nodules, so often found associated with these sandstones, were seen at the base of G^4, some of them being clay ironstone. The *Spirifera mesocostalis* of these sands is the variety with extended ears, moderate area, median septum developed in the ventral valve, and reduplicated fold in the sinus.

476 G (loose). In the bed of the creek near G were found slabs of conglomerate, resembling very closely those met with in the stone fences above Rushford and of which distinct traces were found in place at 476 C^2. Although we cannot identify the horizon of these loose slabs with precision, the evidence is strong that they were deposited before the Chemung fauna ceased. The sources of the Caneadea Creek are high up in

the hills to the north and west in the towns of Lyndon, Farmersville, and Centreville, and nothing has been discovered to show that any of these hills run above the rocks bearing Chemung fauna.

The pebbles are flattened and range from coarse sand to fine gravel. Ironstone concretions are contained in the mass; when not weathered, the matrix is decidedly calcareous, and, while the pebbles themselves are often dark colored, green, and smoky quartz, the iron stain, upon weathering, coats them brown, giving the weathered slabs a chocolate brown color. Several fossils are found in the mass, though not in condition to identify always with certainty.

Spirifera mesocostalis, the second type, with finer plication and extended wings, and well develoved median septum.

Streptorhynchus Chemungensis, of good size.

Orthis, sp., several fragments too imperfect for specific identification.

Rhynchonella ? Sappho, var.

Numerous worn fragments of fish bones, and a fish jaw, *Dipterus Nelsoni* Newberry.

This resembles Newberry's *Ctenodus serratus* in general form, but the teeth are not serrate, although slightly wrinkled along the edge, which might possibly be the result of attrition of a serrate tooth.

While revising the manuscript in March, 1886, I submitted this specimen to Prof. J. S. Newberry, who identified it with *Dipterus Nelsoni*, a species which he has described from the fish beds at Warren, Pa. It is somewhat smaller than the original of that species. The matrix in which it is embedded is also very similar to that of the Warren fish bed.

DESCRIPTION OF FISH REMAINS.

Dipterus Nelsoni Newberry, ms. Plate III, Fig. 1.

This is a small jaw, referred to this species after comparison with Professor Newberry's original specimens from Warren County, Pennsylvania. The grinding surface is of hard enamel, triangular in shape, grooved by seven grooves radiating from near one angle, which is smooth and rounded and divided into finger-like ridges. The tops of the ridges and bottoms of the grooves are subangular. The ridges are arranged in pairs, every other groove running back a little farther than its neighbor toward the angle from which they radiate, and each ridge is slightly notched by four or five constrictions on the side; these notches are only superficial, and upon the crest of the ridges produce only faint undulation, no definite serration. The dimensions of the specimen (No. 16055 U. S. Nat. Mus.) are: length, 20^{mm}; width, 11^{mm}; length of the process of the jaw vertical to the grinding surface, 11^{mm}.

The original is from a gravel-like conglomerate found at Rushford, Allegany County, N. Y. (loose), but traced to the midst of Upper Chemung rocks and associated with Chemung fossils.

Dipterus (?) lævis Newberry, ms. Plate III, Fig. 2.

This is a small and worn specimen, evidently distinct from *D. Nelsoni* and possibly a worn representative of Dr. Newberry's species *D. lævis*. It is nearly as large, but proportionately shorter; the grinding urface has but four finger-like ridges, which are smoothly rounded nd hard; the bottoms of the grooves are also rounded. It is smaller nd has fewer ridges than the typical specimens of *D. lævis*, and, while his may partly be the result of attrition, it is with some doubt that I efer it to the species, and in case future discoveries prove it to be disinct I would propose *D. Alleganensis* for this form. It occurs in a fine ebble conglomerate at Little Genesee, Allegany County, N. Y., in the Jpper Devonian.

uba, Allegany County, N. Y.—477.

Cuba, the third township north from the State line and in the westrn tier of townships in the county, is situated about fifteen miles north f Pennsylvania and thirteen miles south from Rushford, 476. The Erie Railroad grade is given as 1,542 feet above sea; the altitude of the grade f the canal railroad (Rochester division, Buffalo, New York and Philaelphia Railroad) is called 1,488 feet. Several exposures were examned on the hillsides, all at about the same level.

477 A.—The Armstrong quarry is extensively worked just above the Erie Railroad near the depot. Some ten or twelve feet of good buildng stone can be quarried here; the base of the quarry is about thirty eet from the railroad, or nearly 1,570 feet in altitude. Several courses f solid, even grained sandstone lie above the base, with some intervenng layers of shale or shaly sandstone. Below the sandstone are some wenty feet of soft, fissile shales, bluish at the bottom, tending to olive oward the top, and weathering iron stained.

477 B is three-quarters of a mile north, on the same level, and is now bandoned—the old Guilford quarry.

477 C is Smith's quarry, on the east side of the valley and a mile nd a half northeast of A on the same level. The quarry rock is a ight gray, calcareous sandstone, strongly bituminous upon fresh fractre. The grain is generally fine, and though working easily when fresh s more tenacious than the Berea sandstone of Euclid or Amherst, Ohio; ut the grain is coarser than the Portage sands and of lighter color. Jpon weathering there is enough iron to give the stone a creamy to ellowish brown tint. This ferruginous quality is associated with the hinner, more flaggy structure; the purer, thicker courses are of a ighter and purer gray color. The lowest course, from which thick labs are blasted or wedged off, running from three to four feet thick, nakes the finest quality of building stone. A second thick course in he center of the quarry furnishes three to four feet thickness of stone, n which occasionally are seen *Verticalis* perforations on the upper layers. Above this the courses are thinner, rarely furnishing over a foot of

sandstone. Between the layers of shale in these sandstones are the brachiopods.

There appear to be two quite distinct faunas present in the quarry. Although the upper layers of sandstone are very similar in general character to the lower, more strongly calcareous deposits, generally the lower thick beds carry scarcely anything but a lamellibranch fauna, with occasionally an *Orthoceras*. The lamellibranch fauna is generally found in the midst of the solid sandstone, with *Grammysia communis* as its most abundant species. The brachiopod fauna occurs higher up in the thinner sandstone, where the argillaceous matter is so interstratified as to make poor building stone and the shells (in the principal layer) are so thick as to make the stone unfit for cutting. In the fauna the *Spirifera disjuncta* is the most abundant form and lamellibranchs are rare, though occasionally a single specimen of *Sanguinolites* appears at the base or top of the stratum.

Below the sandstones are exposed some twenty feet of soft, fissile shales, A[1] and A[2], containing another distinct fauna. Only a few specimens were found, but those were well marked *Lingulas* and a few other forms. The *Lingula* is the more conspicuous and frequent form, and it is indistinguishable from the Ohio *Lingulas* of the Cleveland shale at Euclid, Ohio. These lingula shales are, however, light in color at the base, the ordinary blue shale, and toward the top are light olive green upon weathering.

Lingula fauna of 477 A[2]:

Lingula Melie.
Chonetes lepida, or small *C. scitula.*
Palæoneilo, sp., a small form.
Discina, sp.
Sanguinolites rigidus (=*Sphenotus contractus* Hall, 1885).

Grammysia fauna of 477 A[3]:

Grammysia communis.
Grammysia communis, var. approaching *G. cuneata.*
Grammysia communis, var. very short.
Schizodus rhombeus, var.
Aviculopecten, a variety near *A. cancellatus.*
Edmondia ? Philipi.
Pterinopecten suborbicularis.
Orthoceras pacator ?
Crinoid stem fragments.

Brachiopod fauna of 477 A[6]:

Spirifera disjuncta, abundant.
Rhynchonella contracta, small var., frequent.
Streptorhynchus Chemungensis, frequent.
Athyris Angelica, frequent.
Chonetes scitula.

Productella costatula.
Productella, sp.
Ceriopora, sp.
(*Crenipecten ? impolitus.*)
Sanguinolites rigidus (= *Sphenotus contractus* Hall, 1885).

The first four species constitute the main bulk of the fossils; the remaining species are represented by several specimens in the lot collected, but are not common. *Spirifera disjuncta* is very abundant in quarry A, and with few *Streptorhynchus Chemungensis*, while the latter species is almost as abundant as the spirifer in some layers of 477 B.

Guilford Quarry, Cuba, N. Y.—477 B.

Sandstone, massive gray, weathering brown; some layers highly ferruginous, the fossiliferous layers decomposing by solution of calcareous matter and producing brown rottenstone. Some pebbles are seen, but no regular conglomerate layers. In the lower sandstone is the lamellibranch fauna, as in 477 A. Above is a thinner layer, more calcareous, filled with brachiopods.

Brachiopod fauna of 477 B:

Spirifera disjuncta, abundant.
Streptorhynchus Chemungensis, common.
Chonetes scitula.
Rhynchonella contracta, var. small.
Productella onusta.

The *Streptorhynchus* is gibbous, often extremely so, and the *Spirifera disjuncta* has the median fold duplicated.

Smith Quarry, Cuba, N. Y.—477 C.

The lithological and stratigraphical characters are essentially the same as in the Armstrong quarry, 477 A.

The brachiopod fauna is the same, though *Productella* and *Streptorhynchus* are more frequent than in the more southern exposure at A.

The fossils obtained are:

Spirifera disjuncta.
Streptorhynchus Chemungensis.
Productella onusta.
Rhynchonella contracta, var.
Rhynchonella duplicata ?
Athyris Angelica.
Pleurotomaria, sp., a finely striated form.
Sanguinolites rigidus (=*Sphenotus contractus* Hall, 1885).
Productella, near *P. arctirostrata.*
Ceriopora, sp.

The brachiopod fauna of these three Cuba quarries is in all essential points identical with the fauna of 476 B^x.

Ravine in South Cuba — 477 E.

Near the base of this ravine there are some thin sandstone layers, but, comparing it with the Cuba quarries a mile or two north, I judge that the first exposures at the base of the ravine are stratigraphically equivalent to the upper part of the Armstrong quarry and that the fine quarrystone layer is below the surface. The shales predominate throughout, though in the lower part some solid sandstone strata, a foot or more thick, are seen. The ravine begins (the first rock exposure) at about 1,600 feet altitude and rocks are visible to nearly 1,725 feet.

Near 1,625 feet altitude or a little higher is an abundant brachiopod fauna, in a calcareous sandstone seam (E^2), with the same species in general as in 477 C, the *Spirifera disjuncta* and *Streptorhynchus Chemungensis* both abundant, and the more common species. Above this stratum no strong seam of sandstone occurs; there is an alternation of thin arenaceous layers, with prevailing argillaceous shales.

Near the middle of the ravine is a layer of rather coarse micaceous sandstone (E^4), 18 inches thick; soon above this traces of red coloring begin to appear in the generally olive argillaceous shales. These argillaceous shales become prominent at about 1,700 feet altitude and continue to the top of the ravine. At several places they run into brown or red shale, and one layer of several inches is strong brownish red and contains fossils (E^5).

Brachiopod fauna of 477 E^2:

Spirifera disjuncta.
Streptorhynchus Chemungensis.
Chonetes scitula.
Rhynchonella contracta.
Productella hirsuta.
Productella costatula, and varieties.
Ceriopora, sp.
Crinoid stem fragments.
Grammysia communis, var.

In thick greenish shale (E^3):

Spirifera disjuncta.
Streptorhynchus Chemungensis.
Leptodesma, near *L. sociale.*

In brownish sandstone, near bottom, 477 E^4:

Athyris Angelica, abundant.
Rhynchonella contracta, var.
Productella, sp.

Above E^4 the rocks are generally argillaceous, and, while generally olive green in color, contain streaks of red and brown and some thin

streaks or nodules of oölitic red iron ore. The fauna of these beds is probably uniform and the reddening of the shales does not prevent the presence of numerous fossils.

Fauna of 477 E^5:

Orthis Leonensis, abundant.
Lyriopecten, sp. = ? *L. orbiculatus.*
Rhynchonella contracta, small.
Spirifera disjuncta.
Ceriopora sp., abundant.
Aviculopecten cancellatus ?.
Leptodesma, sp.
Athyris Angelica ?

Station 477 H is a low bluff alongside the stream which runs into the Cuba valley from the southeast, and is situated about two miles nearly south of Cuba. Stratigraphically the rocks are apparently the soft argillaceous shales following the quarry sandstones of Cuba and are nearly equivalent to 477 E^1, at the base of section E, which lies only half a mile north of H. The shales are normally bluish in tint, being slightly ferruginous, weather to an olive color, tending to a brownish shade; they break up into fissile flakes after weathering, but the bedding is not so fine as to give the true fissile character to the rock in mass.

The fossils are numerous in some layers, in others rare. In the beds examined, the *Chonetes* is most abundant; the *Athyris*, *Streptorhynchus*, *Productella*, and *Spirifera* frequent, the other species rarer. With the exception of *Spirifera* and *Streptorhynchus* the species are generally small.

The following species were identified in the fauna of 477 H:

Chonetes scitula.
Streptorhynchus Chemungensis.
Productella costatula.
Athyris Angelica.
Spirifera disjuncta.
Orthis Leonensis, small size.
Ceriopora, sp.
Crania, sp.
Palæoneilo brevis, var.
Palæoneilo, sp., near *P. filosa.*
Palæoneilo, sp., a minute form, possibly young.
Rhynchonella contracta, small var.
Pleurotomaria filitexta.
Leptodesma, a minute specimen.
Leptodesma sociale ?
Goniophora Chemungensis, small.
Mytilarca Chemungensis.
Centronella Julia ?

Crinoid stem fragments.
Aviculopecten cancellatus.
Modiomorpha ?

Following up the valley from 477 H southeastward, two exposures were met with near the southern boundary of Cuba township. They are about 2½ miles south of 477 A and respectively 2 and 2½ miles east of the same point. Stratigraphically they lie above the section 477 E, station 477 G being not far above the top of E, and 477 F is some 60 feet higher.

Fauna of 477 G, in the sandy layers, weathering brownish to dark bluish brown:

Spirifera disjuncta.
Athyris Angelica.
Plant remains.
Rhynchonella, sp.
Bellerophon, sp.
Chætetes, sp.

In the soft, coarse, argillaceous shale, weathering brownish olive, were:

Rhynchonella, sp.
Palæoneilo, imperfect specimen.
Leptodesma Mortoni ?

Fauna of 477 F, in greenish, arenaceous shale:

Spirifera disjuncta.
Streptorhynchus Chemungensis.
Chonetes scitula.
Sanguinolites rigidus (=*Sphenotus contractus* Hall).
S. clavulus and a variety resembling *Nyassa arguta* in general form.
Palæoneilo Bedfordensis.
Mytilarca Chemungensis.
Leptodesma Mortoni.
Plant stems.
Leptodesma potens.

A comparison of the several faunas from Cuba and the immediate neighborhood gives the following as the general character of the two hundred feet or so which we are able to examine.

(1) Olive green to blue, argillaceous shales with a *Lingula* fauna, when most pure and fine, as seen in 477 A¹ and 477 A².

(2) This is followed by sandstone, locally, of solid, massive character, calcareous and often strongly impregnated with petroleum. Where this sandstone is purest and most massive, the fauna is mainly lamellibranchs. In the more argillaceous layer, where the alternating arenaceous and argillaceous deposits are more frequent and mingled, one of the typical Upper Chemung brachiopod faunas appears, with abundance

of *Spirifera disjuncta*, and in some exposures and layers *Streptorhynchus Chemungensis* is common (477 A, B, and C).

(3) Above the sandstones appear shales again, of the olive, argillaceous character, varying from pure, fine, soft shale to arenaceous shale with more or less iron stain. In this zone *Athyris Angelica* may be found, lamellibranchs of several genera, and several of the common species of the sandstones below.

(4) Next appear traces of those iron gray, micaceous sandstones, so common in the lower Catskill rocks further east, and streaks of red iron ore and red shales. The red shales still contain Chemung brachiopods, *Spirifera disjuncta*, and other species. The most characteristic brachiopod is a small *Orthis* (*O. Leonensis*); this occurs quite abundantly in a thin, arenaceous, reddish brown shale. Here, too, in the midst of the soft, olive shales is seen red oölitic ore, but only in thin veins or nodules. It is interesting to notice that in the lowest clay iron nodules of Chemung and Tioga Counties, New York, in the midst of the same Upper Chemung brachiopod fauna, are seen the representative of the *Orthis* of that section as well as the more typical form of *O. Michelini*, showing conclusively that this type of *Orthis* is associated with nearness to shore conditions of habitat.

(5) Above this the Chemung brachiopods come in again; also a new lamellibranchiate fauna. This time *Leptodesma*, *Sanguinolites*, and *Avicula* are more common, and this rock is a fine, arenaceous shale, from bluish to olive gray in color. This is 477 F and G. Traces of pebbles are seen in the lower sandstones; some of them are an inch in diameter, but no collection of pebbles forming conglomerate was seen. In this section are seen, for the first time going up, distinct masses of red iron ore.

The brachiopod fauna (477 A and 477 C) is remarkable for the absence of any trace of *Spirifera mesocostalis* or *Orthis impressa;* and *Strophodonta Cayuta*, *Productella lachrymosa*, *Orthis Tioga*, and *Cryptonella Eudora* are entirely absent, unless we may regard *Orthis Leonensis* as a small variety of *O. Tioga* and some of the gibbous forms of *Productella* as extreme varieties of the common form of the eastern section. Yet all these species are common in the typical Chemung fauna of the Chemung and Tioga County sections. Several of these species do not appear at all in this Wyoming-Allegany County section, while such species as *Athyris Angelica*, the gibbous varieties of *Productella*, and the smaller varieties of *Rhynchonella contracta* and *Rhynchonella duplicata* appear to be wanting in the eastern section, though often abundant in the Allegany County section. This difference in fauna cannot be geological, for it characterizes the whole Chemung group fauna. We can only look, therefore, to geographical conditions to explain the faunas.

Some of the species of the eastern Chemung do appear at the base of the Chemung fauna in Allegany County, such as *Spirifera mesocostalis*, *Orthis impressa*, and the common Chemung *Leiorhynchus*; but it

becomes evident upon comparison of the two sections that upon passing upward the characteristic Chemung species mentioned above become more and more strictly confined to the east. Again, the species which appear associated with Chemung species in the Allegany County section and that are wanting farther east are of the same types and, in some cases, the same species which are characteristic of Lower Carboniferous rocks of the States farther west. The conclusion appears plain that with the passage of Upper Devonian time over Western New York territory there was a shifting of the faunas in an easterly direction, and that with such shifting species which are regarded as belonging to a later period, when they occur more isolated in the western interior, appear in the western part of New York before the close of the Chemung fauna, but farther east, in Tioga County, do not appear at all up to the close of the Devonian. This study of the faunas gives us a hint toward solving the relation of the eastern and western beds.

If the Waverly or Lower Carboniferous fauna may be regarded as a separate and complete fauna, it was doubtless a local one, and it may be regarded as probably contemporaneous with a part of the Upper Devonian of New York. The indisputable evidence we have that during this Upper Devonian epoch the faunas were moving eastward over Western New York gives reason for the belief that species which belong to a later horizon must have come in from the west, and that the normal contemporaneous faunas farther west were of a later type than in the east. Examination of the species confirms such views. The *Productellas* of 477 C are frequently of the very gibbous form, agreeing in this respect with specimens from the section 476 B[4] of Rushford. Although the specimens are generally smaller, the larger specimens are very like the larger Waverly forms (Geol. Surv. Ohio, Vol. II, Pal., Pl. 10) mentioned by Meek, and the *Streptorhynchus Chemungensis* from these beds reaches a very gibbous form not readily distinguishable from Meek's *Hemipronites crenistria* of Ohio. The *Palæoneilo* of these Cuba beds is different from *P. brevis* in the features distinguishing Meek's *P. Bedfordensis* from that species; it is, therefore, a variety approaching the Ohio Waverly type. The crinoid is of the Waverly variety of *Forbesiocrinus communis* type, as here recognized by stems, but in the fauna of 479 A[4] represented by some specimens of the calyx.

We observe just under these rich fossil bearing calcareous sandstones, 477 A, a series of fissile shales bearing a fauna of *Lingula* and other small delicate shells. Although the fauna is not strictly identical with that of the lingula shales of Van Ettenville, described in U. S. Geological Survey Bulletin No. 3, the stratigraphical sequence is the same and the general character of the fauna is similar. In that section the rich Chemung brachiopod fauna immediately follows the soft lingula bearing shales, and no similar shale was discovered below until within two or three hundred feet above the Genesee shale. In the western section the lingula bearing black shales are constantly recurring for a thousand

feet above the typical Genesee shale, but this soft, olive mud shale, with *Lingula*, does not appear below this horizon (477 A).

In these lingula shales, in both the eastern and the western sections of New York, we find the first traces of the ironstone nodules, and the brown color from iron stain becomes more conspicuous above this horizon, and this marks the lower part, if not quite the beginning, of the common marine fauna of the Chemung group. In the Ithaca section we observe a fauna resembling the Chemung fauna some eight hundred feet below the genuine Chemung fauna. It is preceded by a similar dark lingula shale, but the absence of *Spirifera disjuncta* and the rarity and small size of *Productella* alone suggest the fact that the Chemung horizon, as it is known in Western New York, has not been reached.

From these comparisons we conclude that the Van Ettenville shales and the following fossiliferous sandstones are the stratigraphical equivalents of the Cuba shales and its sandstones as seen in the Armstrong quarry. The interval below, down to the Genesee black shale, is mainly filled by rocks carrying Portage faunas in the Allegany County section, while the section of Tompkins and Tioga Counties holds a fauna only a few hundred feet above the Genesee shale, which is paleontologically intermediate between the Hamilton and genuine Chemung faunas.

Black Creek, New Hudson Township, Allegany County, N. Y.— 478.

This station is northeast of Cuba, about five miles from the Armstrong quarry (477 A), and estimating from the canal railroad (Rochester div., Buff., N. Y. and P. R. R.) grade by aneroid barometer, the quarry is approximately at the same altitude as the Cuba quarries, not far from 1,575 feet. The quarry has been extensively worked, but is now abandoned. At the base is a heavy course of light colored sandstone, running from two to three feet thick; next above, five feet of thin layers of sandstone and shale; then two feet of solid sandstone, followed by a fossiliferous zone of a foot or so containing the brachiopod fauna, 478 A^4; above this is another solid sandstone three feet thick, above which the thinner alternating shaly and arenaceous layers predominate. The lithological characters correspond very closely with those of the Cuba quarries, but the fauna differs slightly in its prevailing characters.

The tracing of actual equivalency of horizon is a matter of considerable difficulty on account of the absence of exposures at intermediate points. According to Prof. James Hall's original section, generalized for this part of the State (see Ann. Rep. of N. Y. Geol. Survey, 1838), a general dip of something like fifty feet to the mile is represented, and each of these quarries at Caneadea, at Rockville, &c., is in a separate zone in the series, separated from others by considerable thickness of deposits. My examinations lead me to the opinion that the general dip of these upper strata is by no means so great, and that there are also long folds in the strata, giving at some exposures even a decided dip

to the north, thus complicating the task of following strata from exposure to exposure in traversing the country.

Knowing, as we do, that the faunas are considerably modified as we pass from east to west, even in a hundred miles, it should not surprise us to find a like difference between the more northern and more southern faunas of the same horizon. The differences in the faunas may be due to differences in geographical conditions on the same horizon or they may be modifications of the fauna, marking geological range or difference of horizon. The present fauna, to all appearances, is at the same altitude now as the Cuba brachiopod fauna, 477 A. At the Cuba quarry the dip is slightly southward. At this station the strata are as nearly level as we can read; at Rockville, three miles farther north, there is a decided dipping to the north. From these facts the conclusion is strong that there is a gentle anticlinal fold near Cuba, sloping northward as we reach Rockville and already showing its southward slope at 477 A.

The fauna of 478 A[1] shows differences pointing to the characters of more eastern faunas or those that are met in the exposures farther north than 477. The presence of *Orthis impressa*, the broad winged, high beaked *Spirifera disjuncta*, and the presence of *Spirifera mesocostalis* may be noted in this connection. In making comparison of faunas, too, we find the same peculiarities in station 481 A, which is actually less than fifty feet higher than 478 A, and nine miles north and a little east, with the rocks again dipping northward, though at intermediate points the dip is decidedly southward.

If we consider each of the sandstone beds as relatively local, when a particular horizon is concerned it is more probable that the sandstone deposits for continuous geological epochs (at least for such length of time as the Upper Chemung may require) were nearly continuous, but shifted their geographical position, than that there was any total cessation and renewal of their deposition.

When we compare the faunas in similar or like lithological conditions, as a tentative rule (which further investigation may modify), we make the supposition that likeness in the composition of two faunas, i. e., the association of the same species, is more apt to persist through the gradual changes brought about by time and that constancy in the lesser varietal characters is more likely to signify likeness or equivalency in geological horizon; hence, if we have two faunas in apparently like conditions of matrix and in the same general geographical area, if the species are the same and those abundant and those rare maintain the same comparative relationship to the fauna, we infer that the fauna is the same. If the species show the same varietal peculiarities, we say the horizon is synchronous; if the varietal characters differ, we say it is probably a different horizon, although the species are identical. Hence in an imperfect fauna, the lack of the full complement of species might signify geographical shifting of the fauna, but if the species that did

appear presented the identical varietal characters, we would infer that the horizon was identical.

Fauna of 478 A^4:

Spirifera disjuncta, large, broad, mucronate form.
Athyris Angelica.
Rhynchonella contracta.
Crinoid stems.
Productella acutirostra, var.
Spirifera mesocostalis.
Orthis impressa.
Chætetes, sp.

The *S. disjuncta* is abundant; the other species are only occasional. The *Productella*, sp., is a large form, with the outline (dorsal valve) of a large *P. arctirostrata*, with strong concentric wrinkles at the cardinal end of the shell, the front geniculate, the interior pitted like *P. hirsuta*. It does not agree with any of the ordinary New York forms, and in general resembles the carboniferous types, but is doubtless a variety of the gibbous Upper Devonian type of *Productella*, and near the form called *P. acutirostra* in the reports. The same form is seen in 479 A^4.

Rockville, Allegany County, N. Y.—479.

Situated in Belfast township, about nine miles northeast from Cuba (477); altitude, approximately, as determined from railroad grade and by aneroid barometer: A^1, 1,410 feet; A^7, 1,460 feet. The section near the old canal lock at Rockville is visible for about fifty feet. At the base is a thick sandstone seam (A^1), six feet of it being visible. A^2 is shale of two feet thickness, then a second seam of sandstone two feet thick (A^3). This is followed by shales and thin arenaceous layers for thirty-five feet, and at the top are two seams of sandstone less than a foot thick, separated by shales. The principal sandstones of the series are massive and of the deeper gray color of the true Portage sandstones, considerably darker than the Cuba stones and of finer grain, and have a strongly bituminous odor on fresh fracture. The shales are green to olive, soft, argillaceous, and do not differ materially from the soft shales which frequently appear in the Chemung series. The rocks dip evidently to the north, not extensively, but enough to show plainly that we are on the northern slope of a gentle anticlinal.

The brachiopod fauna is in the first and second sandstones; the most numerous fauna is just at the close of the second sandstones, in the soft shales, 479 A^4. The upper sandstones are tough but thin, of a pinkish tinge, and contain minute streaks of brown iron ore. There is occasionally seen a passage of the sandstones into a local bed of gravels, with fine pebbles, flat and of a dark and even black color. These are cemented in a calcareous matrix.

Fauna of the calcareous sandstone, 479:

Spirifera mesocostalis (common).

Sp. disjuncta (rare).
Orthis impressa.
Rhynchonella contracta.
Streptorhynchus Chemungensis.
Productella hirsuta.
Ambocœlia umbonata (rare).
Sanguinolites rigidus (=*Sphenotus contractus* Hall, 1885).
Crinoid stems (large).
Bellerophon mæra? (frag.).
Nucula, sp.?
Platystoma, sp.?

Fauna of the olive shales, 479 A[4]:

Spirifera mesocostalis (of smaller and finer structure than that of the sandstones).
Productella hirsuta.
Productella lachrymosa, var. *stigmata.*
Productella (with several varietal forms running off toward *P. onusta* and *P. speciosa*).
Chætetes, sp. (a branching form, quite abundant).
Mytilarca Chemungensis.
Rhynchonella contracta (running into the form called *R. sappho*, var., by Prof. James Hall, Geol. Surv. N. Y., Pal., Vol. IV, Pt. I, Pl. LV, Figs. 49, 50).

The above species are found in abundance; the following are less common:

Spirifera disjuncta, a small variety, with very high beak, in general form and size closely agreeing with the Iowa *S. Whitneyi* Hall.
Orthis impressa.
Productella rarispina.
Athyris Angelica.
Orthis Tioga (or var. *O. Leonensis*), rare.
Crania, sp.?
Bellerophon, near *B. Euclid.*
Palæoneilo brevis.
Macrodon Chemungensis.
Modiomorpha subalata?
Modiomorpha quadrula.
Loxonema styliola.
Ptychopteria, a form near *P. Eugenia* (=*P. Salamanca* Hall, 1885).
Crenipecten obsoletus.
Crenipecten crenulatus.
Pterinopecten suborbicularis.
Aviculopecten, sp.?, a very finely striate fragment.
Forbesiocrinus communis.
Crinoid stems, another species, with nodose joints.
Chonetes scitula.

Belfast Quarry, Belfast, Allegany County, N. Y.—480

This is an exposure about three miles east of the Rockville section, approximately 50 feet lower, or from 1,340 to 1,360 feet in altitude.

The sandstone (480 A¹) is fine grained, of a darker shade and finer texture than the Cuba stone, and very similar to the Arcade stone (474 A). It also closely resembles the Rushford stone (476 G⁴). The color is gray, with a slight brownish or chocolate tint, which changes upon weathering to a purer gray. It is calcareous and upon fresh fracture has the petroleum smell so common to these sandstones. Some layers are flaggy and separated by thin partings of mica. At the top of the quarry are very uneven layers, as if violent action of the sea had disturbed the bottom, making it uneven with pitholes. There are small masses of shale mingled with the sandstone and large irregular masses, calcareous agglomerations of pebbles or fine gravel (480 A²). These have something of the nature of concretions, but are mainly coarse sand and fine gravel cemented by calcareous mud.

In these were found the only fossils of the station. Above and below the sandstones the rocks are thinner layers of arenaceous and argillaceous shales, with no thick layers and no traces of fossils visible.

Fauna of the concretionary masses, Belfast, 480 A²:

Orthis impressa, large, broad variety.
Productella hirsuta, with spines from cardinal margin.
Spirifera mesocostalis, third var., with median septum.
Rhynchonella contracta, approaching the *R. eximia* type.
Ambocœlia umbonata.
Athyris Angelica.
Crinoid stems, same as in 479.
Leiorhynchus sp.
Productella onusta.
Chætetes, sp.
Streptorhynchus Chemungensis, var.

Caneadea, Allegany County, N. Y.—481.

The examinations at this station were confined to the exposures along Caneadea Creek, up to E. Rushford (481 C), and two exposures (481 A and 481 B) made in the hill a few miles northwest of Caneadea by persons who supposed they had found a gold mine.

The altitude of Caneadea railroad station, based upon the profile of the old Genesee Valley canal — in the bed and along the towpath of which the Rochester division of the Buffalo, New York and Philadelphia Railroad is built — is 1,224 feet above tide. This benchmark I have not been able to identify precisely. By aneroid barometer, the cliff above 476 G is estimated to be 1,490 feet in altitude. The cliff to the base, G°, is 140 to 150 feet, or say 1,350 feet in altitude. The other stations, according to

aneroid reckoning, are, 481 A, 1,600 feet, and, 481 B, 1,700 feet in altitude.

The dip of the rocks in the creek is very slight, but what there is is northward. At 476 A two or three miles north of Rushford the dip is strongly northward, and at the base of the creek the rocks incline to the southwest.

Shean excavation, above Caneadea.—481 A.

This section is an opening made on the farm of Mr. Shean, near the division line between Caneadea and Rushford Townships, about two miles in direct line northwest of Caneadea village. It was opened on the supposition that gold and silver ores were there in rich quantities. The report of this "silver mine" I heard of at several places in the county. By aneroid estimate the altitude is about 1,600 feet.

The rock exposed is mainly a gray calcareous sandstone, highly fossiliferous. The stone varies in the amount of calcareous matter. In the more compact portions the sandstone is of a dark bluish gray color and the matrix appears to be almost pure carbonate of lime; but where the sandstone is loose textured it is a pure light gray, with little or no carbonate of lime.

The facts suggest that the difference is due to a solution and removal of the lime from the more compact variety to form the loose textured, light gray variety. The presence of petroleum in the porous sandstones probably had no relation to the original deposition of the sandstones, but wherever these beds of calcareous sandstone were made porous by removal of the carbonate of lime the conditions were present for the absorption and retention of petroleum distilled from underlying black carbonaceous shales. The sandstone weathers a little brownish, but the iron stain is very slight. The sandstone becomes coarse in places, forming a fine gravelly conglomerate, with flat and dark colored, silicious pebbles, the matrix calcareous, and containing fragments of fish bones, shells, and chips of wood very similar to 476 C^2.

The fossils in 481 A are:

Ambocœlia umbonata, abundant.
Productella (*lachrymosa*, var.? see beyond).
Productella hirsuta, var., small.
Rhynchonella contracta.
Spirifera mesocostalis, second var. with strong median septum, and third var. coarse and with reduplicated fold.
Orthis Tioga.
Orthis impressa, larger.
Streptorhynchus Chemungensis.
Rhynchonella, sp.? (like *R. Horsfordi*, broad).
Crinoid stems.
Chætetes, sp., slender branching form.

? *Lingula*, with punctate inner layer.
Spirifera disjuncta.
Aulopora, sp.
? ? *Cryptonella*, sp., a fragment.

Caneadea Creek, lower part.—481 C.

This is the section referred to in Geology of Fourth Dist., N. Y., p. 485, as "a good exhibition of the characteristics of the base of the Chemung group of this part of the State, better than is elsewhere seen." The distinction between this section and those of Steuben County consists mainly in the prevalence here of the "pure aluminous shale of a deep green or bluish green color," with intervals only of thin sandstones. The green shales referred to prevail in all the lower part of this ravine. I would describe them as a fissile, greenish gray shale, argillaceous, weathering brownish with iron stain, and containing at intervals streaks, from an eighth of an inch to several inches in thickness, of hard, silicious sandstone, the surface of which is often rough and uneven and sprinkled with mica grains. In the upper parts, from 476 G upward, the sandy layers are more conspicuous and thicker and of looser texture and coarser grain, forming strata of a foot or more in thickness. These are referred to in another place.

The shales contain a few fossils as low down as Caneadea, but there they are rare and are mainly *Leiorhynchus mesocostalis* and *L. multicosta.* A single *Rhynchonella sappho*, var., was found, and a *Productella*, which, though differing from any particular figure and description, is probably a variety of *P. hirsuta.* This general character of deposits continues up to the base of the cliffs at 476 G. an account of which is given in another place.

Friendship, Allegany County, N. Y.—491.

The exposures at Friendship were examined at Mr. P. Miller's quarry and in the ravines south of the village. They lie at about the same altitude as the Cuba quarries and above them and are directly east of Cuba. Substantially the same series of rock deposits and the same faunas were met with as in the ravine south of Cuba (477 E). In the higher exposures the micaceous flags were reached; a red band was seen before the close of the Chemung fauna.

Mr. Miller showed me several fine specimens of *Dictyophyton*, two of which were presented by him to Cornell University. They came from a fine compact sandstone lying above the Chemung fauna. The sandstones exhibit traces of the same polished quartz gravel seen in the same layers of the Cuba sandstones.

Wellsville, Allegany County, N. Y.—492.

There is a quarry on the hillside at Wellsville a hundred feet above the railroad, the top reaching over 1,600 feet elevation above tide. In

this quarry the prevailing rocks are a brownish gray sandstone, in not very thick courses, thin bedded micaceous shales, and soft, fragile olive shales, with an irregular seam of fossiliferous, red, arenaceous shale.

In the sandstone are—

Spirifera disjuncta, abundant.

Productella hirsuta.

Ambocœlia umbonata.

A large, flat, fish scale, the surface broken off so that it cannot be determined; but the nature of the bone still preserved is like that of *Holoptychius*.

Ceriopora, sp., casts showing the form of branching, but no structure.

In the soft olive shales—

Rhynchonella contracta.

Productella costatula, var.

Ceriopora, same as above.

The red shales are oölitic in spots and also contain streaks of fine polished pebbles. The fossils are generally in imperfect condition; the fish remains are in broken fragments. The following species were recognized:

Spirifera disjuncta, rare.

Goniophora Chemungensis, small, and with rather coarse concentric striæ.

Mytilarca, sp., small, and presenting characters between *M. occidentalis* and *M. simplex*.

Macrodon Chemungensis, small.

Grammysia communis.

A small *Orthoceras*, an *Aviculopecten*, a *Crenipecten*, and a small *Palæoneilo*, none of them perfect enough for specific identification.

The branches of *Ceriopora*, sp., seen in the other shales, and among the grains a few minute spiral shells.

In the same quarry are seen layers, or rather large lumps, of a sort of pudding of white sand, mingled with small nodules of green clay and streaks of mica flakes.

This condition of rock appears to indicate a transition of conditions, in which considerable disturbance took place, but the break indicated was so slight that the mud at the bottom was still mud and not consolidated into rock when the sand was thrown down upon it.

Very similar characters were seen in the sandstone quarry at Arcade. The horizon of this quarry is considerably above that of the Cuba sandstones, but between it and the Wolf Creek conglomerate.

Belmont, [illegible]y, N. Y.—493.

Thi[illegible] called Phillipsburg in the New York State geologic[illegible] which many species are quoted.

[illegible] which is quarried in several places in the neighbor[illegible], calcareous, and with petroleum smell. It is under[illegible] shale, as is the case with the Cuba sandstone. It

lies at about 1,450 feet elevation and represents very closely the horizon of the Rockville sandstone, 479.

Some of the more common species are—

Spirifera mesacostalis, second and third varieties.
Orthis impressa, large.
Streptorhynchus Chemungensis
Rhynchonella contracta.
Grammysia elliptica.
Productella hirsuta.

Hornellsville, Steuben County, N. Y.—494.

On my return eastward I stopped at Hornellsville, where I made an examination of some cliffs along the railroad west of the town, at which point is exposed a section of about a hundred feet, beginning at the base at 1,200 feet elevation, the railroad grade at the station being 1,161 feet above tide.

Running eastward along the Erie Railroad from Allegany County, the summit at Alfred, elevation 1,793 feet, presents some cliffs of heavy sandstones and shales which are well up in the Chemung; but as we go down the grade no strong sandstone layers are met with as far as Hornellsville, elevation 1,161 feet, and from there to Elmira, elevation 863 feet, the whole series is made up of alternate layers of arenaceous shales and stiff seams of thin bedded sandstone of a prevailing dark brownish gray, no light or pure grays appearing, nor are there any of the gray sandstones marking the Upper Portage and Lower Chemung of the Wyoming-Allegany section.

For topographical and stratigraphical reasons I thought that at about this point, which is intermediate between the two long sections of Tompkins-Tioga Counties and Wyoming-Allegany Counties, would be found the horizon at which the Portage and Chemung faunas meet. Stratigraphically it should lie not far from the horizon of the Portage sandstones of Portage Falls, and for similar reasons, looking eastward, it should lie several hundred feet above the horizon of the Ithaca shales. Upon examining the rocks I found it even more important than I had expected. The general appearance of the cliff is very similar to those in Caneadea Creek below Rushford, but here there are none of the light colored sandstones of Allegany County.

The section (494 A) presents the following lithological characters and faunas from below upward:

(1) A stratum of very dark, almost black, shale appears at the base; this is lithologically identical with the upper black streaks underlying the Portage sandstones at Portage Falls.

(2) These black shales are followed by soft fragile shales, olive gray in color, and bearing a very interesting fauna, marking very decidedly the transition between the Portage and Chemung faunas.

The species identified were the following:

Cardiola speciosa, common (= *Glyptocardia speciosa* Hall, 1885).

Palæoneilo plana, var. A small form frequently seen in the Portage shales; it appears indistinguishable from *P. plana*, except that in size it is much smaller

Coleolus acicula.

Coleolus (Coleoprion) tenuicinctum.

Fragments of a small *Orthoceras* and of *Goniatites* of the *G. bicostatus* type.

Productella speciosa, a single valve of small size.

Fragments of *Cladochonus* and of crinoid stems.

Orthis Tioga, several specimens, small, but with the characteristics of that species.

The *Cardiola* and the *Palæoneilo* of this shale (which are the principal fossils, the others being of rare occurrence) are identical with those of the last olive Portage shale of the section at Portage Falls, (see p. 51), and the whole fauna, except the *Productella* and the *Orthis*, is purely Portage in character.

(3) Above this are coarser shales and thin layers of argillaceous sandstone, staining brown in places, with occasional thin streaks of light or nearly white sand in the midst of the olive shales, just as they occur at station 476 G, in Caneadea Creek below Rushford, in which was found the earliest appearance of Chemung fauna for the eastern part of that section.

The fauna of this zone, 494 A³, was as follows:

Leiorhynchus multicosta, running into the form *L. mesocostalis.*

Ambocœlia umbonata.

Productella speciosa, a few specimens.

Spirifera mesostrialis, a single specimen, but with the characteristic markings.

Spirifera mesocostalis, a single poor specimen

Orthis Tioga, larger than those below.

Rhynchonella Stephani ?, a coarse variety approaching *R. contracta.*

This fauna is in its main features like a forerunner of the Chemung fauna occurring a few miles south of Ithaca, lying far above the Ithaca fauna. The *Leiorhynchus* and *Ambocœlia* are the common species; the others are rare or seen in a few specimens. The list of species taken as a whole is similar to that of 476 G⁰, at the base of the Chemung series in Allegany County, although the *Orthis* of that fauna is *O. impressa*, while this one is *O. Tioga*. This, however, is evidently a geographical feature, as the common species of *Orthis* in the Chemung faunas of Allegany County is *Orthis impressa*, while *O. Tioga* is the more common form in Tioga and Chemung Counties.

(4) Immediately following are more sandy layers, with Chemung fauna wherever fossils occur in them.

In one slab several good *Spirifera mesocostalis* were seen, all marked with the strong median septum not developed in the specimens living at the Ithaca stage. This single section throws considerable light upon the history of the faunas we are studying. Geographically it lies between the two main sections already fully developed. One of the most striking differences between those two sections is seen in the interval between the Genesee shale and the zone containing the first *Spirifera disjuncta*.

In Wyoming County this interval is filled by a long series, of a thousand feet or so, of black and olive shales, containing respectively the Lingula fauna of the Genesee and the *Cardiola speciosa* fauna of the Portage, and is terminated by thick deposits of gray sandstone.

In Tompkins and Tioga Counties the black shales terminate a short distance above the Genesee; a special Portage fauna, the *Spirifera lævis* fauna, occurs near the base of the Portage; a few hundred feet higher a rich brachiopod fauna, that of the Ithaca group, occupied the field. While two or three hundred feet of sediments were depositing, this fauna withdrew and the *Cardiola speciosa* returned, and is occasionally seen in the almost totally barren, flaggy, arenaceous shales and sandstones, until at about the same distance above the Genesee shale, as in the more western section, the Chemung fauna begins to appear with the first *Spirifera disjuncta*.

The stratigraphical conditions help us very little in interpreting these differences, except that the coincidence of the occurrence in each section of the first good representation of the *Spirifera disjuncta* fauna in a bed of heavy calcareous sandstone is suggestive of a common horizon.

The fossils of the Hornellsville shales show us definitely where we are in the history of the faunas. Stratigraphically these shales are at the general horizon of the passage beds of Portage Falls, and, compared with the eastern section, near the point at which the genuine Chemung fauna first appears.

The fossils show that the Portage fauna is still intact, even in the presence of a characteristic species of the true Chemung fauna, *Orthis Tioga*. The presence of this species, instead of *O. impressa*, shows that we are dealing with an eastern extension of the fauna. The *Spirifera mesocostalis*, with strong median septum in the ventral valve, as well as the *Orthis*, is evidence that we are far above the stage of the Ithaca fauna.

Taking all the facts together, we could scarcely hope to find stronger confirmation of the hypothesis advanced in my report in U. S. Geological Survey Bulletin No. 3 that from a paleontological point of view the Ithaca group and its fauna are really intercalated in the midst of the deposits which in western counties are regarded as one continuous series on account of their fauna holding its integrity from the beginning to the close. I regard, therefore, the Ithaca fauna as a separate, earlier stage

of the Chemung fauna, intermediate between it and that of the Hamilton group and occupying an intermediate position; while the special fauna of the Portage shales is a more general one, probably of partially pelagic character, less restricted in both geographical distribution and geological range, but during the Middle and Upper Devonian making its appearance where the conditions were unfavorable for the more vigorous brachiopod faunas, and rarely, except at points of transition to another zone, mingling with any brachiopod fauna.

CHAPTER IV.

THE UPPER CHEMUNG—THE SANDS AND THE CONGLOMERATES.

As we pass above the principal Chemung faunas we find coarse, flaggy sands, red beds, and conglomerates. The conglomerates are of two kinds: The first is composed of smooth, gravel-like pebbles, with layers of flat pebbles, and is called the *flat pebble conglomerate.* The higher is composed of large, coarse pebbles, not much worn, and sand; this is the *Olean conglomerate* and its equivalents.

The exposures of these deposits were examined at Clarksville, 483; Little Genesee, 484; and Bolivar, 485, all in Allegany County, New York; at Portville, 486; Olean, 487; Great Valley, 490, of Cattaraugus County, New York; and at Bradford, 488, and Alton, 489, in McKean County, Pennsylvania.

Clarksville, Allegany County.—483.

This station is six miles south of Cuba and upon higher ground, the hills running up to two thousand feet above tide level. The rocks exposed are of a geological horizon higher than the highest of the Cuba section, but the base of the Clarksville section is the same paleontological zone as that seen in the ravine south of Cuba (477 E).

In the township of Clarksville, including the upper part of Wolf Creek, where the flat pebble conglomerate is seen in full development, we find the passage from the olive shales and the thin bedded sandstones of the Upper Chemung, with their typical fauna, through the coarse, yellow sandstone and flat pebble conglomerate with an occasional jasper pebble, which, all through this region, is recognized as the first of the Devono-Carboniferous conglomerates, and thence up into the green and red, arenaceous shales and those green, micaceous shales, of a loose and mealy texture, so characteristic of the Catskill deposits farther east.

The lowest exposure (483 A^2) examined in this locality was a ledge cropping out in a small run about half a mile northwest of the railroad station at an altitude of approximately 1,745 feet above the sea. Near this, in the same side hill, is the second exposure (483 A^1), from nine to ten feet higher. The rocks at these exposures are green, argillaceous shales, with thin, flaggy sandstones and arenaceous shales with fossils.

The green shales (483 A^2) contain the following species:

Rhynchonella contracta, numerous, large, and variable.
Leptodesma Mortoni, var., of the form of *L. potens* and *L. Mortoni* Hall.
Plant remains, chips, and fragments of stems.

In 483 A[1], a few feet above A[2], the shales are more arenaceous and darker, are iron stained upon weathering, and, though they contain the same *Leptodesmas*, the principal fossils are brachiopods. The sandy layers are micaceous, and though dark have a trace of the mealy texture peculiar to the green Catskill rocks as they appear farther east. One slab contains —

Athyris Angelica.
Leptodesma Mortoni, var.
Productella hirsuta, var. near *P. hirsuta*, but not the typical form.
Traces of *Rhynchonella*, sp., *Spirifera*, sp., and crinoid stems.

In other slabs *Spirifera disjuncta*, *Athyris Angelica*, and the *Leptodesmas* are associated.

Taking the species occurring within two or three feet of one another as of a single zone, we have the following fauna for 483 A[1]:

Spirifera disjuncta, the most frequent species.
Athyris Angelica, common.
Rhynchonella contracta, small variety.
Leptodesma, sp., of the *L. Mortoni* type, some specimens approaching *L. robustum* and others *L. potens*.

And of the following species single specimens are rare:

Spathella typica, Hall, distorted, resembling *Nyassa arguta.*
Mytilarca Chemungensis.
Productella costatula, var., a small form of the type of *P. costatula.*
A trace of a *Pterinopecten*, sp.
Sanguinolites rigidus (=*Sphenotus contractus* Hall, 1885).
? *Macrodon Chemungensis.*

On the eastern side of the valley is a very steep, high hill, rising rapidly from the valley, and on its side the rocks occasionally crop out, not in solid strata, but in broken pieces, disintegrating rapidly, and partly covered by soil. The order of the rocks composing this hill is easily traced by these loose pieces on the surface, but it would not be safe to place any dependence upon the actual altitude of occurrence of any particular stratum. This is 483 B. The place for the lower conglomerate is between the base, about 1,880 feet, and the top, approximately 2,110 feet, in altitude, but I found no trace of the genuine conglomerate on it. The lowest rocks appearing contain the same fauna found on the other side of the valley, at 483 A. The rock is a dark, arenaceous shale, micaceous in some layers and weathering brownish. At the base of the hill, and within the first 120 feet, the above are the prevailing characters and the following species were detected as constituting the fauna of 483 B[4]:

Spirifera disjuncta, frequent.
Productella costatula.
Rhynchonella contracta, small var., and approaching the type *R. duplicata.*
Chonetes scitula, rare.

A small *Chætetes*, sp.
Orthis Leonensis, same as seen in the red beds of 477 E and green shales of 477 H.
Mytilarca Chemungensis, small var.
Athyris ? Angelica, probably *A. angelica*, but near the form of *A. polita*.
Sanguinolites clavulus (=*Sphenotus clavulus* Hall, 1885).

In the upper portion of this part of the section, 483 B^4, traces of the conglomerate are seen in the form of fine pebbles, with oblique bedding on the ordinary dark brownish gray sandstone.

A slab, one side of which is thus turned into conglomerate, contains a fine specimen of *Grammysia subarcuata*. Another slab, with the same *Grammysia*, contains also some imperfect *Rhynchonellas* of the *R. contracta* type. Large oblique *Leptodesmas*, of the *L. Mortoni* type, appear in the same association.

Above these fossiliferous shales (B^4) occur light colored green shales, not calcareous, but breaking up into lumpy pieces. They are arenaceous and with streaks of the fine green mud shales (B^3). Above these are thin, fragile, red shales, first in thin streaks with the green, but the top of the hill is a rich red earth of several feet in thickness, composed of the disintegrated red shales.

As well as can be determined from surface indications the uppermost hundred feet is composed of alternation of the green and red shales, some layers micaceous and mealy, others fine red mud shale, constituting the specimens designated 483 B^1, B^2, and B^3 in the collections, and at an altitude from two thousand to twenty-one hundred feet above sea level.

It is perfectly evident on ascending this hill that we pass from the Upper Chemung zone through the zone which in other places is represented by a conglomerate, the first or flat pebble conglomerate, and pass upward a hundred feet at least into the estuary or brackish water deposits represented in the green and red shales, devoid of fossils and often micaceous and presenting the peculiar mealy appearance so characteristic of the barren measures which separate the typical Chemung deposits from the conglomerates, forerunners of the Coal Measures.

Ascending the hill on the west side of Centerville Valley, or Dodge's Creek, and passing over into the valley of Wolf Creek, on the eastern slope, we find the same conditions. At the base traces of the Chemung fauna are seen for one or two hundred feet, then we run into the green and red shales, with traces of the flat pebble conglomerate intervening at an altitude of about 1,950 feet, above which the green and red shales hold on uninterruptedly to the top of the hill, over 2,100 feet high, and the micaceous structure is more frequent, with a tendency to form evenly laminated layers, separated by deposits of nearly pure grains of mica. As the mica grains are more abundant so also are they larger than in the rocks of the same horizon on the hill a couple of miles farther east. As we descend the western slope, into Wolf Creek Valley, we find traces of

the conglomerate at the point of junction of the Chemung fauna bearing rocks below and the green and red barren shales above, and across on the west side of Wolf Creek Valley, near its head, is a fine representation of the flat pebble conglomerate.

The altitude of outcrop of this conglomerate on both sides of the hill is not far from 1,950 feet, and above 2,000 feet no conglomerate or fragments of it are seen. But in the small runs below this altitude large blocks of the coarse sandstone, merging into fine conglomerate, with streaks of larger flat pebbles, are frequent. On the extreme top of the hill, which by aneroid was estimated to be 2,250 feet above sea level, a loose block of nearly white sandstone with a few pebbles was found, but no outcrop. This may be a drift from the second conglomerate, but the several hundred feet of green and red shales below it preclude the idea of the occurrence of the first flat pebble conglomerate at this altitude.

Wolf Creek conglomerate. – 483 C.

This conglomerate is best seen near the head of Wolf Creek, over the hill directly west of Clarksville, or "Centerville Station." The main mass of it lies between 1,950 and 2,000 feet in altitude (aneroid estimate), and it may be fifteen or twenty feet in thickness; at no place were both top and bottom seen exposed. In the bed of the stream are large blocks of it from six to ten feet thick. Its general character is a coarse, loosely agglutinated, silicious sandstone, of a yellowish color, in some places stained strongly brown, at other places bleached nearly white, obliquely laminated, with the direction of the obliquity reversed several times during its deposition, containing streaks of coarser gravel, and occasionally becoming a thick mass of gravel and flat, white, silicious pebbles, with an occasional pebble of red jasper.

The fossils occur at or near the top, where the rock abruptly changes into the ordinary brown gray, arenaceous shales, with distinct traces of the Chemung brachiopod fauna again. The animal remains of the conglomerate, 483 C, constitute a characteristic fauna recognized in several other places under like conditions. At this locality numerous chips of carbonized wood were found, as well as the following species:

Palæanatina typa, abundant.
Modiola præcedens, common.
Cyrtoceras ? Hector, several specimens.
Orthoceras ? sp. = ? *O. Demus*.
Goniophora Chemungensis, single specimen.
Leptodesma lichas ? resembling *L. lichas* Hall.
Spiraxis ? Randalli, var. Newberry.[1]
Spiraxis ? major Newberry.

[1] The name *Spiraxis* is preoccupied for a genus of Gasteropoda, by C. B. Adams, 1850. I propose, therefore, for this genus the name of *Prospiraxis*.
JUNE 1, 1887. H. S. W.

These last two peculiar spiral fossils are identified with *Spiraxis* described by Prof. J. S. Newberry in the Annals of the New York Academy of Sciences, Vol. III, No. 7, p. 220 (read December 10, 1883). Neither of them agrees precisely with the figures or specimens described by Professor Newberry; but, as the specimens themselves are imperfect and from study of these and other known specimens it is found that the detailed characters presented by their peculiar forms are not uniform, it is believed that the truth is more nearly reached in referring them provisionally to these species than it would be if an attempt were made to make them the types of new species.

Little Genesee, Allegany County, N. Y.—484.

Genesee is the next township south of Clarksville and lies next to the State line. The "rock city"[1] north of Little Genesee, 484 A, is about five miles south and a little east of the Wolf Creek conglomerate exposure west of Clarksville, 483 C. On the southern slope of the hill on the top of which "rock city" is situated traces of the Wolf Creek conglomerate were seen in slabs and blocks between the elevations of 1,925 and 1,975 feet. The rock was not seen in place, but fragments of it were met several times along this zone and none above. The small flat pebbles were very distinct from the round and larger pebbles of the second conglomerate of the "rock city." Along the railroad, from Clarksville to Little Genesee, as well as in the sections on the hillsides, the series of strata were in the same general order as at Clarksville. No extended exposure was discovered where the precise thickness of the individual masses could be measured.

The Chemung fossils were rarely seen above the horizon of the first (Wolf Creek) conglomerate and but for a short distance. After the green, micaceous, and flaggy shales and the soft, red iron shales had fairly set in, the Chemung fauna ceased.

With the incoming of the second conglomerate of Little Genesee "rock city," there was deposited a coarse mixture of clay, iron ore, and yellow sand with fossils.

DESCRIPTION OF RHYNCHONELLA ALLEGANIA.

This ferruginous sandstone is characterized by a *Rhynchonella* of large size, differing from any species lower in the series, but it also contains frequent specimens of *Spirifera disjuncta*, linking its fauna with the Chemung fauna below. I propose to call it

Rhynchonella Allegania, n. sp. Plate IV, Figs. 1–8.

This is a large rhynchonella, peculiar in this section to the coarse, ferruginous sandstones following the Chemung and found, generally, not far below the Olean conglomerate. It occurs in the form of empty

[1] The term "rock city" is applied to the massive conglomerates as they appear capping the hilltops in several places in the southern counties of New York. In Cattaraugus County, six miles south of Olean, a station of the Olean, Bradford and Warren Railroad, built upon one of these "rock cities," has received the name of Rock City

impressions in the coarse sand, but presents features separating it from the usual form of any of our Devonian rhynchonellas. Of the New York forms it approaches more nearly *R. orbicularis* or some varieties of *R. Sappho*. It appears identical in specific details with specimens I have seen in collections from Ohio marked *R. Sageriana*, but from the description of that species I believe it to be quite distinct. The costæ are more numerous than in the typical form of any of these species, from 10 to 13 being on each side of the center. It bears a close resemblance to some Eifelian varieties of *R. laticosta*, and the gutta percha cast of the exterior of a dorsal valve, represented in Plate IV, Fig. 3, is very close to *R. princeps* Barrande (Fig. 12, Plate CXX, Syst. Sil. Bohême). But after considerable study of the specimens and comparison with Devonian rhynchonellas I am led to the conclusion that it is scarcely more than a varietal modification of the rhynchonellas from the ferruginous sandstones of Licking County, Ohio, called *R. Sappho*, var., by Prof. James Hall and figured in Geol. Surv. N. Y., Pal., Vol. IV, Part I, Figs. 47–52, Plate 55, p. 354.

In the form in which it is here represented it appears quite distinct, and I therefore propose the name *Rhynchonella Allegania*. The characteristics of this form are its large size, the broad, flat sinus and fold including five to seven well defined, rounded plications; the broad, flat, tongue-like platform representing a depression in the shell itself, under the beak of the ventral valve (Plate IV, Fig. 8); the well defined serrations of the cardinal teeth seen in Fig. 1; the presence of a strong but short median septum in the dorsal valve (Figs. 1 and 4), with an elongated rounded beak of the ventral valve, perforated near the extremity (Fig. 7).

The specimens have been found in the ferruginous sandstones underlying the conglomerate at Olean and Little Genesee, in New York, and at Bradford, McKean County, Pa. In the larger forms the tongue shaped platform for muscular attachments in the beak of the ventral valve is very broad and flat, giving a peculiar appearance to the casts, unlike the ordinary rhynchonellas of the Devonian.

The same rhynchonella occurs just below the Olean conglomerate at Rock City[1] (487 A[3]) in the same associations and in a ferruginous sandstone of the same character. On the way up the hillside to Rock City loose slabs were met with, though not found in place, presenting the same order of occurrence as at Clarksville.

Along the zone of the first conglomerate were found several slabs of the same character of rock and bearing the fossils of 483 B[4], i. e., *Grammysia subarcuata*, and some specimens running into the *G. communis* type, as figured by Prof. James Hall, and *Sphenotus clavulus*, with one specimen closely approaching the form called *Allorisma Winchelli* of Meek. In these gray, shaly sandstones *Spirifera disjuncta* appears; also *Rhynchonella contracta*.

[1]See note, p. 87.

Flat pebble conglomerate also occurs here with *Spirifera disjuncta*, *Rhynchonella contracta*, with traces of a *Bellerophon*, sp., and a bryozoan. In this fine pebble conglomerate, fish teeth appear, one very similar to that met with in a similar conglomerate, found loose in the bed of the creek at Rushford = a *Dipterus* tooth (*Dipterus ? lævis* Newberry); also conical teeth resembling those of *Holoptychius;* but only the casts are preserved, so that it is impossible to identify them with certainty.

This section confirms the order of these upper rocks as interpreted at Clarksville. After the regular gray green shale of the Chemung, with its brachiopod fauna (rich in *Spirifera disjuncta* and often containing *Rhynchonella contracta*), has passed its meridian and is nearly terminated, a flat pebble conglomerate is deposited locally. Sometimes the conglomerate contains seams of large flat pebbles, at other places it is a thin stratum of fine, very hard pebbles, often containing black and greenish quartz, all highly worn and bearing fish teeth, together with *Spirifera disjuncta*, or, where the conglomerate is several feet in thickness, it is terminated by a coarse sandy deposit, with the unique fauna of *Palæanatina typa* and *Mytilarca Chemungensis* and *Modiola præcedens*, with *Orthoceras* and the peculiar coiled stems which Professor Newberry has referred to the genus *Spiraxis*. (See note, p. 86.)

Above this conglomerate it is rare to find any Chemung fossils, but they do not entirely cease till the second conglomerate of 484, Genesee "rock city," the Olean conglomerate. Between the two conglomerates are red and green, argillaceous shales (the former sometimes bearing Chemung fossils), with flaggy, micaceous, green shales and sandstones. The intervals between these two conglomerates may average about three hundred feet, but the first conglomerate varies considerably in thickness and probably varies in the precise position it occupies in the series, since it probably represents a shore line which must have occupied consecutively a higher and higher position as the slow elevation brought it farther seaward from its earliest position.

Bolivar, Allegany County, N. Y.—485.

The rocks about Bolivar were examined, and, although no extended exposures were met with, all the evidence obtained confirmed the order of the series as already given. Bolivar is about four miles east and perhaps two miles north of station 484, at the "rock city," Little Genesee. The region for a radius of a mile or more is perforated by oil wells, and although, as above said, no good rock exposures were seen, there are along the steep hillsides slabs and broken pieces of rock which, from their very order alone, show that they are not far from their source. I collected the surface rock at various elevations on the hillside in the northern part of the town, on the "oil farm" of Varney & Co., and, upon examining the material, I afterwards found it arranged in the same order as in other sections in the county. The elevations must be regarded as only approximate, but for general purposes they are valuable.

Supposing the railroad station to be 1,600 feet in elevation, we find the greenish gray shales of the Chemung with some gray sandstone, containing *Spirifera disjuncta*, *Rhynchonella contracta*, and *Sphenotus clavulus*, up to 1,800 feet elevation. The flat pebble conglomerate occurs on the surface from this level upward for fifty feet, and in this conglomerate we still find *Spirifera disjuncta.*

Above an elevation of 1,850 feet the coarser gray sandstones are more conspicuous, with red shales and mottled arenaceous shales; toward the top, or above an elevation of 2,000 feet, coarse, micaceous and ferruginous sandstones are the prevailing surface rocks. From such a series of specimens we recognize the general position of the section. It is substantially the same as that seen on the hill separating Clarksville from the valley of Wolf Creek (see section 483 C), but as a whole lies a hundred feet lower down. The position of the flat pebble conglomerate is between 1,800 and 1,875 feet in elevation, and at Clarksville it is near 1,950 feet.

I obtained from Mr. W. T. Reed, the obliging superintendent of the Varney & Co. wells, the measurements from the mouth to the top and bottom of what are called by the oil men the "third sand," in this oil field being known as the "Richburg sands." As usual, the first oil sand is here regarded as lying about three hundred feet above the oil bearing third sand, although in drilling the place of the second was not clearly distinguished. Records of nine wells were given, the thickness of the third sand varying from thirteen to forty-seven feet. Taking the records as they are, measuring from the mouth downward, the top of the third sand does not vary over a hundred feet for the nine wells of which a record was made; but the average altitude of the top of the Richburg sand, for this lot of wells, according to aneroid measurements and estimates, is 800 feet above the sea, or something over a thousand feet below the flat pebble conglomerate of the Upper Chemung.

The nature of the "oil sandstone" from well No. 11, at the level mentioned above, after shooting the well, is like the gray sandstones of the surface twenty or thirty miles farther north. It is calcareous and contains a few black grains as well as grains of mica. No traces of fossils were seen in it. It is probable that this sandstone is represented at the surface farther north by the Portage sandstones at Portageville, 482.

Portville, Cattaraugus County, N. Y.—486.

This station is between Little Genesee and Rock City, Cattaraugus County; and the "rock city" of Portville is directly west of Little Genesee "rock city," and between four and five miles distant. The top of the conglomerate (486 A) is at an altitude of approximately 1,850 feet, as determined by aneroid.

The fossils found at its top and the relations of the rock to those below and above leave no doubt of its indentity with the Wolf Creek conglomerate (483 C) four miles to the north. We are able to trace the same

zone in the side hill below the Little Genesee "rock city" and at Bolivar at approximately the same elevation.

The conglomerate is a massive, unevenly bedded, coarse, yellow sandstone, with a few pebbles scattered irregularly through the mass and some beds or layers of pebbles cemented by sand. At the top is a fossiliferous layer containing numerous fossils, the most abundant being *Palæanatina typa*, with several species of mytiloid shells. The pebbles are of the lentiform shape so characteristic of these lower conglomerates, and jasper pebbles are found among them, as in the other flat pebble conglomerates.

Above the conglomerate are dark, thinly and evenly bedded, micaceous shales, and within the next hundred feet are red, argillaceous shales and the greenish gray, micaceous shales characteristic of the deposits between the two conglomerates.

The species identified in this fauna, 486 A, are —

Palæanatina typa.
Modiola præcedens.
Mytilarca? sp.
Rhynchonella contracta, the ordinary type and a small variety.
Leptodesma? sp., a form near the *L. lichas*, Hall.
Orthoceras? sp., apparently identical with the species from the Wolf Creek conglomerate, 483 C.

No Chemung fossils were detected above the conglomerate.

Great Valley, Cattaraugus County, N. Y.—490.

The flat pebble conglomerate forms a "rock city" about six miles south of Ellicottsville, on the ridge separating Little Valley and Great Valley.

The first trace of fossils in loose slabs under the conglomerate is of the same fauna which runs up to the conglomerate at Wolf Creek, Allegany County, and other places in the same region. But in Great Valley I found no fossiliferous ledges in place. The elevation of the top of this conglomerate has already been carefully determined by Messrs. Chance and Hall, and is 2,190 feet above sea level and thirty-five feet thick. (See Report IIII, Second Geological Survey Pennsylvania, J. F. Carll, p. 203.)

The rocks are the ordinary flat pebble conglomerate, with some ferruginous streaks, while the main mass of the rocks is a coarse, yellowish sandstone. The sands are obliquely bedded and the direction of this beach lamination is reversed several times during the formation of the deposit.

The characteristic jasper pebbles are also found; but no fossils were found in any part of the conglomerate.

In all the elements of composition, structure, and color, this corresponds with the conglomerates of Wolf Creek, Portville, and places in Allegany County.

Olean, Cattaraugus County, N. Y.—487.

From Olean upward to the Rock City[1] conglomerate, six miles south of the city, the Upper Chemung rocks are exposed in numerous places, clearly exhibiting the general sequence of faunas and stratigraphical characters.

Olean, at the Buffalo, New York and Philadelphia Railroad depot, is reported as 1,435 feet in elevation; 1,430 feet is C. A. Ashburner's corrected altitude.

The first exposures in the hillsides are of Chemung rocks, containing the *Athyris Angelica* fauna, and for fully two hundred feet, extending to 1,700 feet in altitude, the characteristics of the Upper Chemung are conspicuous. Although thin sheets of red, argillaceous shale are met with in the midst of the ordinary greenish gray, fossil bearing Chemung shales, they become more conspicuous, in thicker masses and associated with coarser, micaceous, flaggy, and barren shales, as we ascend above the fossiliferous parts. The highest exposure of a characteristic Chemung fauna was found in gray, arenaceous shales two hundred and thirty feet below the first sandstone and about four hundred and thirty feet below the base of the Olean conglomerate. A considerable bed of red shales occurs half way between the first sand and this top of the Chemung fauna.

The first sandstone, as determined by examination in several places, is not uniform, but lies between two hundred and two hundred and fifty feet below the base of the conglomerate. This is evidently the sandstone which the oil well drillers on top of Rock City speak of as occurring about three hundred and fifty feet from the top of wells started above the conglomerate. The rock as found in places is of variable character. Below Rock City on the west (487 A^5 and 487 A^6) it appears in a few courses, none of which exceeds eighteen or twenty-four inches, of tough, yellowish, fine grained sandstone; some parts of these are marked by the borings of some worm similar to the *Fucoides verticalis* in the Portage sandstones below, but not more than a quarter as large, and occurring in great numbers, so that exposed and weathered slabs show as many as fifty of the small pittings, due to the deeper weathering of their exposed ends, in the space of a square inch. The lower layers of the sand are generally a little coarser and looser grain, more or less brown iron-stained. Above and below, red, argillaceous shales occur with the ordinary greenish shales, but at this exposure no conglomerate or pebbles were detected. Around on the north side, at the Cook quarry, the same zone is recognized, and at very nearly the same elevation, as determined by aneroid barometer. This is 487 C, the details of which will be given more fully beyond (p. 97). The particular sandstone in question is under a mass of red and green, argillaceous shales several feet thick; it is irregularly bedded, wedging rapidly in some layers from a

[1] See note, p. 87.

thin streak half an inch thick to a bed two feet or so thick and massive. Associated with it are beds of flat and small pebbles, beds containing fragments of plants in abundance, and in the upper layers are the fine vertical borings seen in 487 A[6] and also in the corresponding sandstones of Bradford, McKean County, Pa. The lower layers are of the more massive, fine grained, yellowish brown sandstone. The quarry, however, is principally worked for the excellent thin bedded, blue gray, micaceous flagstones lying below these yellow sandstones.

Above this zone of sandstone and conglomerate the rocks are green and red, coarse, mealy, micaceous shales and flags, and soft, argillaceous shales, until near the base of the conglomerate, where we meet the ferruginous sandstone containing the large *Rhynchonella Allegania* and the *Spirifera disjuncta* so characteristic of this zone.

Study of these sections and close comparison of the specimens from the various localities lead me to the opinion that serially there is a uniformity in the deposits for all of this region in Allegany and Cattaraugus Counties, however the minute details of the local sections may differ.

The characters marking the close of the Upper Chemung epoch are as follows: Deposits of thin bedded, alternating, argillaceous and arenaceous, bluish to greenish brown, fine grained shales containing the last Chemung fauna, with its characteristic variety of *Spirifera disjuncta*, with area high and overarching and not prolonged at the cardinal extremities, *Athyris Angelica* appearing in the softer, argillaceous deposits and *Rhynchonella contracta*.

As these conditions passed away the red shales gradually came in. These first occur as thin layers, appearing occasionally in the midst of the other rocks of soft, red shale; occasionally they contain one or two of the regular Chemung fossils. As we ascend, the red shales are accompanied by traces of the green, micaceous beds; but when the mica shales appear the fossils are very rare or wanting. When the prevailing character of the rocks is evenly laminated, loose textured, coarse grained, and micaceous, we look in vain for fossils.

At this stage in the sequence we look for the first sandy conglomerate. From examination of several sections in different places I am convinced that for these Southern New York outcrops, the first flat pebble conglomerate—carrying often jasper pebbles (with some variation in the thickness of the red shales above the last Chemung fauna and some difference in the extent to which Chemung species run up in the red bearing rocks)—occurs stratigraphically at this place in the series. It is not always a pebble conglomerate, but when only a gritty sandstone it generally contains a few scattered pebbles, and though Chemung fossils may not have entirely ceased at its arrival it is very rare in this region to find any of the characteristic species above it.

Above the flat pebble conglomerates, the red and green, argillaceous shales and the gray, micaceous, and flaggy shales prevail up to the

Olean conglomerate. In this interval are seen the coarse rocks which resemble the Catskill deposits of the eastern part of the State and contain *Holoptychius* and other fish remains. Just below the Olean conglomerate there is a ferruginous sandstone, as at Little Genesee, holding the same fauna, containing among other species the *Spirifera disjuncta.*

The Olean conglomerate is divided into two parts by a thin stratum of black shale, which doubtless represents the zone of the Marshburg upper coal or Sharon group of Mr. C. A. Ashburner (see Report of the Second Geol. Surv. Penn., R.); above this the conglomerate is less pebbly, the sandstone whiter and finer. This upper portion of the "rock city" section I regard as representing Kinzua Creek sandstone of the above mentioned report.

The records of oil wells drilled from the top of the Olean (Rock City) conglomerate agree in their general features with the facts developed by study of the outcrops along the hillsides. The drillers report about eighty feet, at the thickest point, for the conglomerate, including both members. At a depth of 350 feet they report the first strong sand seam of two screws' thickness; below this, "red streaks," but no thick red beds; at a depth of 1,250 feet is another sand of varying thickness, below which no red shales are found. Oil is struck in a sand at a depth of 1,860 to 1,865 feet.

Taking 2,340 feet as the altitude of the bottom of the conglomerate (see Report Second Geol. Surv. Penn., R), the top would be at 2,420 feet in altitude, and the first sandstone at 2,070 feet. The outcrop of this sandstone, as recognized on the hillside, was not so thick as the drillers reported.

At several places at about 250 feet, aneroid measurement, below the base of the conglomerate a massive sandstone was seen, varying greatly in thickness (see 487 A and 487 C). It is composed of a yellowish sand similar to that associated with the flat pebble conglomerates, with pebbles in some specimens. Along the hillside below this horizon were frequently seen large blocks of thick, massive sandstone of the same character, carrying traces of the same fauna met with in the flat pebble conglomerates farther north and east. These large blocks have been extensively used in and about Olean for building stone, and, although they are of an entirely different character from the Olean conglomerate, the actual ledge from which they came is not known, even by the most experienced quarrymen of the neighborhood. From study of the region I concluded that they were probably represented by the thin sandstone called C^3 and C^6 in the Milo Cook quarry. The blocks were found in several places nearly as high as this quarry and scattered on the hillside at all altitudes below, but I did not find one above. The wedge shaped beds of sandstone in that quarry explain the probable nature of the deposit throughout. It was doubtless thick and thin, as coarse sand might be expected to be deposited near a shore, with soft shale partings, which broke up the massive character wherever they were fre-

quent or in thick layers. The more massive beds, when two or three feet thick, stood out during the general disintegration of the hillside, and breaking off finally rolled down the hill, but the massive portions were not continuous or uniform for any distance, and no regular ledge of the rock is detected along the slope of the hill. Seen along the hillsides at about the same horizon and loose below and reported at approximately the same position in the series by the well drillers, and by them found to be the only sand worth mentioning until passing below the red shales, these yellow sandstones show traces of both the flat pebbles and the fauna of the genuine flat pebble conglomerate, and they are the only rocks between the typical Chemung faunas and the Olean conglomerate which bear any resemblance to that zone.

I conclude therefore that, for the Olean section, these yellow sandstones are the representatives of the Wolf Creek, the Portville, and similar conglomerates farther north, east, and west, although they lie apparently higher stratigraphically in relation to Chemung marine faunas and in a more pronounced setting of red shales and green, micaceous shales than do any of the flat pebble conglomerates farther north and west.

This interpretation is further supported by comparison with the sections farther south and east, where the red and green shales and the coarser, micaceous deposits become more and more frequent and of greater thickness previous to the deposit of the great conglomerate, and as we go off in the southeastern direction the flat pebble conglomerate appears to lose its identity in the general increase of coarser deposits all through this part of the series.

Section 487 B.

Along the railroad, ascending the hillside from Olean toward Rock City, the rocks for the first hundred feet are gray, arenaceous shales and shaly sandstone, with some layers of softer, greenish, argillaceous shale, such as is common in the Chemung group. Rising above this, traces of the red shales appear. The lowest clearly marked red shale was seen at about 1,650 feet elevation, or something over two hundred feet above the valley, in the midst of ordinary shales with Chemung fauna. This is at an elevation but a few feet lower and in the same lithological associations as the first clearly defined red band of the section south of Cuba, 477 E.

The Chemung fauna, however, is not recognized much above this red shale; the species are very rare, and the fauna was rapidly disappearing when this six inch stratum of red shale was deposited. This Upper Chemung fauna is clearly marked by the prevailing presence of *Athyris Angelica*, the smaller variety of *Rhynchonella contracta*, and *Productella* of the type of *P. hystricula*. The *Spirifera disjuncta* is here the variety with high, overarching beak and narrow form.

The fossil bearing, arenaceous shales are frequently strongly calcareous, and upon weathering, by solution of the fossils and the calcite, they become cavernous and often are stained brown by iron.

The fauna, as well as the general character of the rocks, shows this series to belong to the same general zone as that represented in the sections south of Cuba, particularly 477 E. The fauna is that which followed the Cuba sandstone, 477 A.

Fauna of 487 B, H, &c.:

Rhynchonella contracta; the large form is rare.

Rhynchonella contracta, var. *saxatilis*. This small form is the common one, and some varieties approach the form called *R. duplicata* Hall.

Athyris Angelica, with some small varieties approaching *A. cora* and *A. polita*.

Spirifera disjuncta. The prevailing form is that of the short, high-beaked type, of small size, figured in Geol. Surv. N. Y., Pal., Vol. IV, Pt. I, pl. 42, figs. 1, 2.

Productella hystricula. The larger specimens approach more nearly the typical form of *P. spinulicosta* (or *P. Shumardiana*) and *P. hirsuta* and *P. onusta;* but the large majority of specimens are small, the ventral valve alone greatly resembling that valve of *P. dissimilis* Hall of the Iowa Devonian and the Lower Chemung beds of New York.

Ceriopora, sp. The hollow casts left by solution of the substance of the organism are frequent, but in such a condition as to forbid certain specific identification.

Sanguinolites clavulus, several specimens, (= *Sphenotus clavulus* Hall, 1885).

Sanguinolites rigidus, or varieties of the other form.

Leptodesma potens and varieties in the direction of the forms *L. Mortoni* and *L. Maclurii*.

Mytilarca Chemungensis, a single specimen.

Fragments of fish bone.

Plant fragments.

Fragments of crinoid stems.

A small, low coiled gasteropod, too imperfect to identify.

A fragment, probably of *Schizodus rhombeus*, but not distinct.

In the greenish shales at the foot of section 487 A (the stratum A[a]) the fauna is apparently the upper part of this same zone, the one seen at Clarksville and Portville just below the flat pebble conglomerate. This is made up almost entirely of *Spirifera disjuncta*, with a few *Rhynchonella contracta*, normal size, and a few *Chonetes scitula* of the later type. This part of the fauna was not reached in section B. In these upper fossiliferous strata the absence of certain species is worthy of mention: *Streptorhynchus Chemungensis* and *Orthis Tioga* and the *Orthis* of the first red beds above the Cuba sandstone are none of them present in these Olean shales.

The arenaceous character of the strata has become prominent, and from this point upward the argillaceous shales are generally red or red alternating with a bright green and contain no marine fauna.

Cook Quarry, south of Olean.—487 C.

This quarry exhibits some points of interest. The base of the quarry is somewhat over 200 feet below the base of the conglomerate at Rock City.[1] It includes the same zone recorded as A^5 and A^6 in the section going down the slope westward from Rock City. It is also the same zone in which occur the last (on ascending) blocks of the fine yellow sandstone extensively used for building at Olean.

Mr. Milo Cook, the owner of the quarry, told me that he had searched in vain for the outcrop of this thick bedded sandstone. His quarry contains a few thin seams of like sandstone, but the main quarrystone is flagging of very fine quality, separated by thin layers of mica and cleaving into large, even flagging stone. The quarry exposes 50 feet of strata for minute examination.

The top of the cliff is covered with earth, lying upon—

C^1. Three to four feet of red, argillaceous shale, soft and compact.

C^2. Two to three feet light green, argillaceous shale, grading above gradually into the red.

$\left.\begin{array}{l} C^3 \\ C^4 \\ C^5 \end{array}\right\}$ Ten feet, unevenly bedded.

C^3. Heavy bedded, gray sandstone, with some mica, but working pretty free; in the thickest part are courses of over a foot thick, from two feet running out to ten or even six inches.

C^4. Thin stratum of fine grained, argillaceous shale, light green, similar to the lower part of C^2.

C^5. Coarse sand, yellowish color, filled with fragments of fossil wood and plant stems of *Ptilophyton* and *Rhodea*, &c., containing pebbles in streaks, flat, and one of them an inch in diameter. This mass is very unevenly bedded and is broken up occasionally by thin sheets of the fine green shale.

C^6. Coarse to fine sandstone, in some parts nearly white, very hard, silicious sand, the upper layers perforated by fine vertical borings filled by the fine green clay shale; surface when weathered pitted by the open mouths of the perforations; ripple marked in some places, with flat pebbles and a few plant fragments, as in C^5. This mass is very uneven; in this one quarry it thins out from four feet to less than an inch in thickness. At this thin edge it lies between sandy shales, with plant fragments and soft, green, mud shale, is folded into regular undulations or furrows

[1] This Rock City is a station on the Olean, Bradford and Warren Railroad, six miles south of Olean.

about an inch and a half apart, the effect of ripple action, and is completely perforated by the small vertical borings above referred to. This is terminated below by a few inches of green argillaceous shale.

C^7. Thirty-five feet dark bluish gray, evenly bedded, micaceous sandstone, very flaggy, cleaving into broad sheets, from one-half inch to six inches thick, the partings glistening with mica. About half way down (sixteen feet from top) is a thin parting of soft, red shale.

C^8. Below the bottom of the quarry, at least ten feet, rock of the same character as C^7, but coarser and unevenly bedded, showing current action, with oblique bedding, the direction of obliquity changing several times in course of the deposition of five feet.

The break between C^7 and the sandstones above is very marked. The sands above are of light color, yellowish and brown gray, with traces of iron stain. Flat pebbles are frequent, though not here found in any large quantity. Although grains of mica are seen, they are merely peppered through the mass of the sand and not spread out in even sheets. The lower sandstones are dark bluish gray, with thin, flaggy bedding, no browning or iron stains, deposited in very smooth, thin sheets with partings of mica grains, making excellent flagging. The better part of the sandstones C^3 and C^6, especially the latter, are similar and equal in quality to the blocks obtained abundantly in the valleys and upon the hillside south of Olean.

The same characters and order of sequence were seen in the section on the hillside westward below Rock City. Below a red, argillaceous shale, A^5, came the thick courses of A^6, with the same fine vertical borings at the top. The sandstone is of the same color and texture as C^6, and below this for fifty feet, more or less, the prevailing rock is the mealy, micaceous flagstone represented by C^7. The elevation is approximately identical as determined by aneroid.

Comparing the lithological characters with those of the flat pebble conglomerates farther east at Portville, at Clarksville, (Wolf Creek), and at Little Genesee, also with that farther west and north, the "rock city" of Salamanca, there is little to distinguish them. Looked at stratigraphically, this is full a hundred feet above the Wolf Creek and equivalent flat pebble conglomerates; but, when we examine the sequence of the faunas, this is the first genuine conglomerate, terminating the Chemung fauna and separating it from the typical red and gray shales of the Catskill conditions. On passing southward along this meridian we find the reds, in relation to the composition of the embedded faunas, taking a lower and lower place in the series, and they become more frequent and thicker; also the gray and green, micaceous flags, presenting a coarse and mealy appearance from the larger size of mica and sand grains, are more frequent and more fully take the place of the finer green and brown

Chemung shales the farther south we go. We also meet more frequently single pebbles in the ordinary fossiliferous shales going the same direction. All these facts point to an approach to the shore line and shallower water. Associated with this change we should expect thicker deposition for each of the strata, and hence the upper strata should not exhibit so great a dip southward as the lower. Thus, in attempting to solve the problems of equivalency between the New York sections of these rocks and those farther south in McKean County, Pennsylvania, I trust to this line of interpretation, based upon the following fundamental proposition, which I believe to be substantially sound: That, for deposits within a single geographical area presenting varying conditions in the nature of the deposits and in the fossils, a more reliable guide for determining equivalency will be found in the continuity of a well marked fauna with persistence of slight varietal characters, than in any uniformity, either in the nature of the sediments, or in their thickness, or in their order of sequence, except for very short distances of separation. And, in general, the coarser the ingredients composing them, the more restricted geographically will be found the specific characters of a continuous deposit.

A mile or so beyond Rock City the upper member of the conglomerate 487 F appears. There are twenty or thirty feet of this sandstone here exposed, which I regard as the representative of the Kinzua Creek sandstone of the Report of the Second Geol. Surv. Penn., R. It is here a coarse sandstone, with few or no pebbles; in the upper layers, particularly, it is purer white than the Olean conglomerate below. At its base I detected streaks of ferruginous shale and sandy shale, and at a point somewhat northeast of the Rock City station, on the top of the Olean conglomerate, I obtained some pieces of slaty coal and arenaceous shale, which Mr. Milo Cook, of Olean, informed me he himself saw dug out in making an excavation when the roads were being cut at the first oil excitement in this region. At that time he saw this black shale in place, and there were some two or three feet of the black shale with streaks of coal, which at the time caused hope of finding coal, but the digging revealed no solid coal, so the search was abandoned. The samples of this shale are marked 487 E^2, and attention is drawn to them as marking the horizon of the Marshburg coal of Mr. Ashburner's report. The whole mass of upper sandstone is of a white color, free from iron stain, and contains little cementing material, and what there is of it appears like fine clay or decomposed feldspar.

Several large stems were seen in this sandstone; one is a fragment of a *Sigillaria* stem.

The lower member, or true Olean conglomerate, corresponding to the conglomerate so defined in McKean County, is better defined as a coarse conglomerate with a sandy matrix and occasional streaks of sand.

Bradford, McKean County, Pa.—488.

After the careful and exhaustive work of Mr. Ashburner in McKean County it would be difficult to add much to the stratigraphical geology of this county as set forth in Report Second Geol. Surv. Penn., R. Mr. Ashburner in 1880 found the rocks from the Olean conglomerate to the bottom of the deepest valley, paleontologically considered, essentially one group, incapable of subdivision (op. cit., p. 292, § 388). But paleontologically the strata are certainly poorly provided with means of discrimination. As, however, the sections in this county, and especially the Dennis well section near Bradford, are authoritative and are extensively used for comparison, I took some pains to locate the fossiliferous zones of the corresponding series of Southern New York in this rock series exposed at Bradford. I examined such rock outcrops as I could find from the valley up the side of Mount Raub to the Olean conglomerate capping it. This is section 488 C; also along the hillside towards the Dennis well, 488 A. The materials collected, while not extensive, were sufficient to illustrate the general succession and position of the several fossiliferous zones. In the valley (1,440 feet at the railroad depot) and running up a couple of hundred feet are found the characteristic bluish gray, argillaceous and sandy shales and the thin sandstones of the Upper Chemung horizon, and in them, abundantly in some of the layers, the species of the upper fauna of the Chemung group.

In 488 C^8, A^1 and B^1, are seen the following species:

Spirifera disjuncta, with high, overarching area.
Rhynchonella contracta.
Productella arctirostrata, running into the type of the var. ***lima*** of ***P. lachrymosa***, are the more common forms.
Ceriopora, sp.
Fragments of crinoid stems.
Leiorhynchus ? globuliformis, or one of that type.
Leptodesma, near *L. Mortoni* Hall.
Grammysia communis.
Palæoneilo.

This is the combination of forms frequently met with in the softer shales of the upper fossiliferous zone of the Chemung. Above this are red shales, gray and green, micaceous, flaggy shales, and sandstones.

A hundred feet or so above the last traces of this Chemung fauna a fine sandstone (A^3 and C^6), with the small vertical worm borings near the top, is clearly distinguished in both sections. This is mainly composed of sand, but also contains stratified layers of pebbles. The pebbles are generally small and smoothly polished, with a few larger flat pebbles and an occasional jasper. This I interpret to be the stratum No. 15 of the Dennis well, described as "S.S. gray, fine, mixed with slate, a few pebbles, specs. 26, 27; —23 feet, elevation 1,817 to 1,840 feet, and referred to the Red Catskill group" by Mr. Ashburner. (Op. cit., p. 288.)

At this zone a few fossils were detected, enough to show to what fauna they belong:

Spirifera disjuncta.
A small fish tooth.
A *Leptodesma* of the *L. Mortoni* type.
Palæanatina typa.
A cast of a lamellibranch, resembling *Schizodus oblatus*, but too imperfect for identification.

There is no place in the more northern sections to which such a fauna in such a rock can be referred, except the flat pebble conglomerate. Between this and the Olean conglomerate the prevailing characters are red and gray shales, greenish, micaceous, thin bedded shales, and sandstones. Not far above the sandstone A^3 and C^6, at C^4, *Holoptychius* scales and *Sauropterus Taylori* were found in thin bedded, shaly sandstone. Above this the only fossiliferous stratum detected is a band of ferruginous sandstone, C^3, in which were found the *Rhynchonella* and *Spirifera* characteristic of a similar ferruginous sandstone underlying the conglomerate at Olean and at Little Genesee.

In the present section this sandstone is separated by over fifty feet from the base of the conglomerate, and it is apparently in the horizon called by Mr. Ashburner the sub-Olean conglomerate of the Dennis well section; but it is not a conglomerate, nor did I discover any stratum of conglomerate except the one mentioned above on the hillside of Mount Raub. The Olean conglomerate is clearly represented at the top, having the same characters as at Olean.

Whatever may be said of the differences between the stratigraphical conditions of this Bradford section and the corresponding five or eight hundred feet under the Olean conglomerate of Rock City, I am persuaded that the sequence of faunas was the same in both cases. The faunas are sparse, both in species and in individuals, but they are clearly recognized in the same order of succession as that borne by them in the sections fartner north. They are not confused: *Spirifera disjuncta*, though found at each zone, presents varietal characters, clearly distinguishing the upper zone from those below. The Lower Chemung form is of the narrow type, with short or rounded cardinal extremities, with high, overarching beak, strong dental lamellæ, and strongly defined fold and sinus, the front produced, as in Figs. 1, 3, 11, 16, and 17 of Plate 42, Geol. Surv. N. Y., Pal., Vol. IV, Pt. I. This type prevails up to the zone of the flat pebble conglomerate, where it is occasionally seen. But in the ferruginous sandstone under the second Olean conglomerate the elongate type occurs, with mucronate cardinal extremities, the plications rather finer, the fold and sinus less strongly defined, the front not produced, approaching the typical characters of the Carboniferous *S. striata*.

I have called them all *Spirifera disjuncta* because a study of the forms appearing in the successive zones, as they are traced step by

step, presents variations which link the prevailing type of one zone with the prevailing type of the succeeding zone. There is a variety in the Upper Chemung faunas which is indistinguishable from some specimens of the Iowa *Spirifera Whitneyi*, but its associations show, indisputably, that it is but a variety of *S. disjuncta* of our Upper Devonian.

Similar statements may be made in respect to many other species, but since it can be plainly demonstrated that the prevailing characteristics assumed by a species at one stage are very frequently, to say the least, not those assumed by it at the next succeeding stage, it will certainly lead to less confusion to use present specific names with some elasticity until the laws of modification shall be clearly distinguished in their relations to both geological range and geographical distribution. At the same time it has been my intention in these preliminary papers to point out any marked variation from the prevailing characteristics of species recorded.

The stratigraphical conditions are not uniform for the Bradford and Southern New York sections. In the Bradford sections there is a greater preponderance of red shales and green, micaceous, flaggy sandstone. Taking, however, the Olean conglomerate above and the gray and green shales with Chemung faunas below as two well defined boundaries, the differences in the intervening deposits for the northern and southern sections seem to me to be best explained as geographical variations in the nature of synchronously deposited sediments. Uniformity in the faunas and in the order of their appearance should testify more positively for equivalency of horizon than difference in the nature of the deposits should against it.

Alton, McKean County, Pa.—439.

The rock exposures south of Bradford lead rapidly up into the conglomerates, and in Lafayette Township we reach the first heavy coal seams of this area.

At Alton and at Buttsville I made a rapid survey of the sandstone and coal deposits and gathered materials for comparison with the sections farther north. No fossils except coal plants were detected. In the coarse sandstone underlying the first Alton coal are coarse stems of *Sigillaria*, apparently identical with those of the upper member of the Olean conglomerate at Rock City.

In regard to the lithological and stratigraphical features of this region little can be added to the excellent work of Mr. Ashburner (see Report Second Geol. Surv. Penn., R.). His Kinzua Creek sandstone is evidently the representative of the upper member of the Olean conglomerate, and the thin mass of black shale and shaly sandstone separating the conglomerate from the coarse sandstone capping the "rock city" represents the Marshburg upper coal of the Pennsylvania reports. The representative of the Olean conglomerate in Lafayette Township I found less massive and with smaller pebbles than the characteristic Olean conglomerate of

Rock City, Cattaraugus County, N. Y., or than that on Mount Raub, above Bradford.

The elevation of the bottom of the Olean conglomerate at Alton is 1,875 feet and at Buttsville 1,924 feet, as given by Mr. Ashburner (op. cit., p. 185). This gives an average dip of about twenty-five feet to the mile from Rock City southward, which agrees with the estimates I had made of the average dip of the upper strata in Allegany County. From all the evidence accumulated from surface exposures and position in the salt wells of Wyoming County of the Corniferous limestone from Genesee County to the edge of Allegany County the average dip is not far from fifty feet to the mile.

CONCLUSIONS.

Prof. I. C. White, in the Report of the Second Geological Survey of Pennsylvania (QQQQ, p. 77), calls the sub-Olean conglomerate of Mr. Ashburner the equivalent of his Shenango sandstone, and, as a sandstone, puts it in the midst of equivalents of Cuyahoga shales of Ohio. The shales below it graduate eastward into the Pocono groups. A study of the reports of Messrs. White and Ashburner, taken with my own examination of the rocks about Bradford, suggests the following conclusions:

(1) The Olean conglomerate is the equivalent of beds lying under the coal in Pennsylvania.

(2) There is a second conglomerate, with flat pebbles, under the Olean conglomerate, which must be regarded as of wide extent.

(3) The Pennsylvania geologists regard this lower flat pebble conglomerate (the "sub-Olean," "sub-Garland," &c.) as lying under the "Catskill" and in the midst of deposits equivalent to the Lower Carboniferous beds of Ohio and the West.

(4) It is recognized by them as lying in the midst of the Pocono group of the Eastern Pennsylvania section.

(5) My section shows it to be at the top of the Chemung and containing a fauna of decided Chemung type, which is distinct in some features, but appears in the shales below.

(6) These underlying shales in New York gradually run into genuine Chemung rocks and fauna and cannot be discriminated from them by any sharp line of distinction.

I have traced the conglomerate and the faunas coming up to it continuously from north to south and observe (*a*) an increase of green, micaceous slates, (*b*) the appearance of red shale (1) lower and (2) thicker, and (*c*) the sand deposits more conspicuous the farther south the section is made.

I conclude, therefore—

(7) That with the geographical passage southward the Upper Chemung beds grow coarser in their sands, the argillaceous bands become more micaceous, and the red bands are intercalated, and are present lower in the series;

(8) That probably the same thing occurred in regard to the higher deposits of the Carboniferous;

(9) That the total deposits were thickened on passing southward by increase in the coarse sands, but that the red and green shales may only take the place of the brown and blue shales farther north;

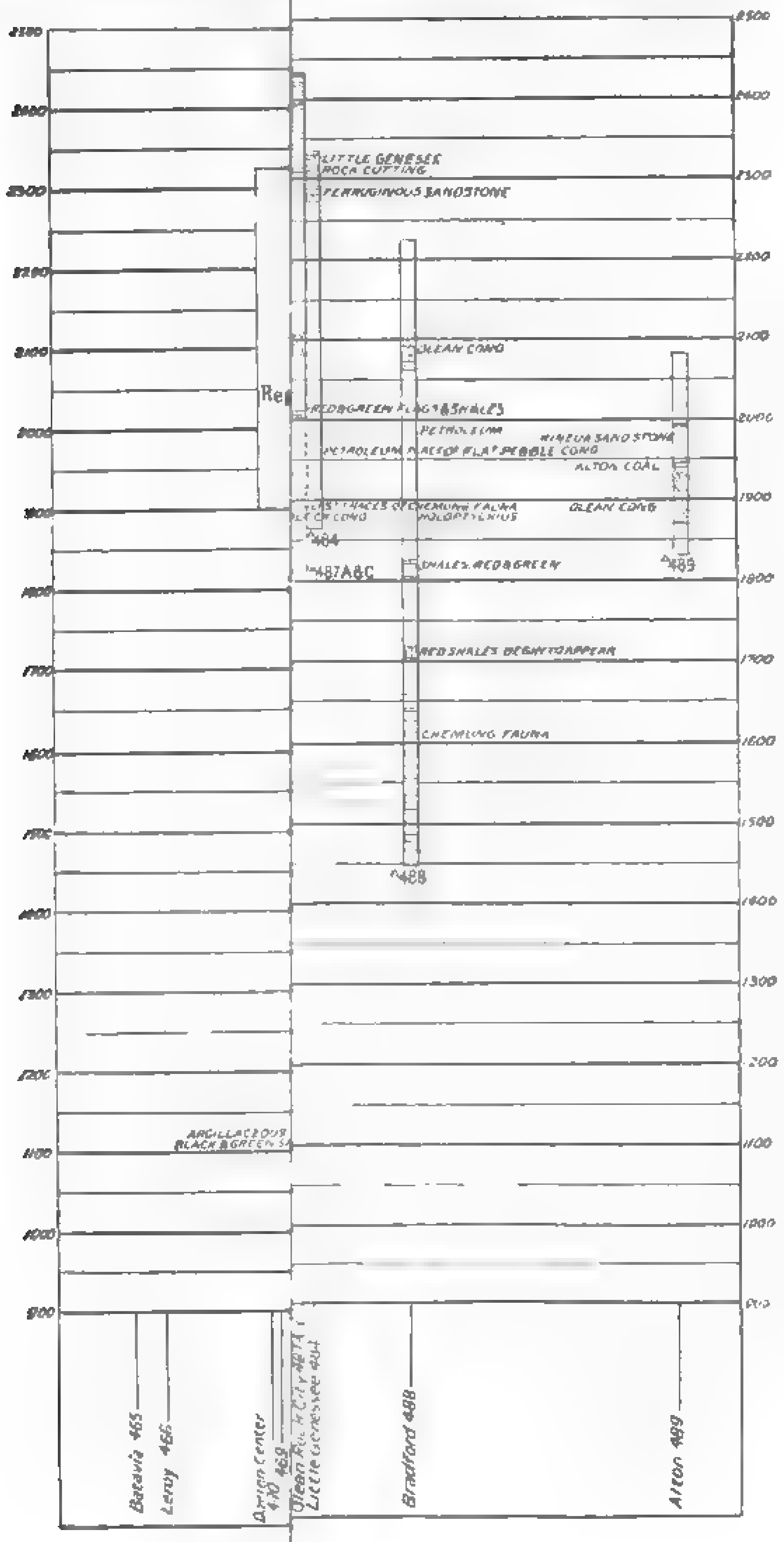
(10) That the sands are purer and whiter by becoming coarser and freer from the brown clay and mud forming the ordinary shaly deposits of the Chemung, in New York;

(11) That with the purer deposit of sand the sands themselves become more massive, and are thus more easily distinguished as sands from the shales between; and

(12) That the increased thickness of the total mass affects the dip of the rocks based upon that of the Corniferous, so that the upper strata are more nearly horizontal over Southern New York and Northern Pennsylvania.

(13) I judge from the numerous facts here arrayed that the conditions for the deposition of red shales were not congenial to the marine fauna of the Upper Chemung group. So long as they were but temporary—represented by thin layers or occasionally intruded in the midst of the ordinary green shales—the Chemung fauna was only temporarily disturbed by their presence, but when they became the prevailing sediment, associated with micaceous, flaggy sandstones and green shales, the Chemung fauna departed.

PLATES.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LITTLE GENESEE
ROCK CUTTING
FERRUGINOUS SANDSTONE
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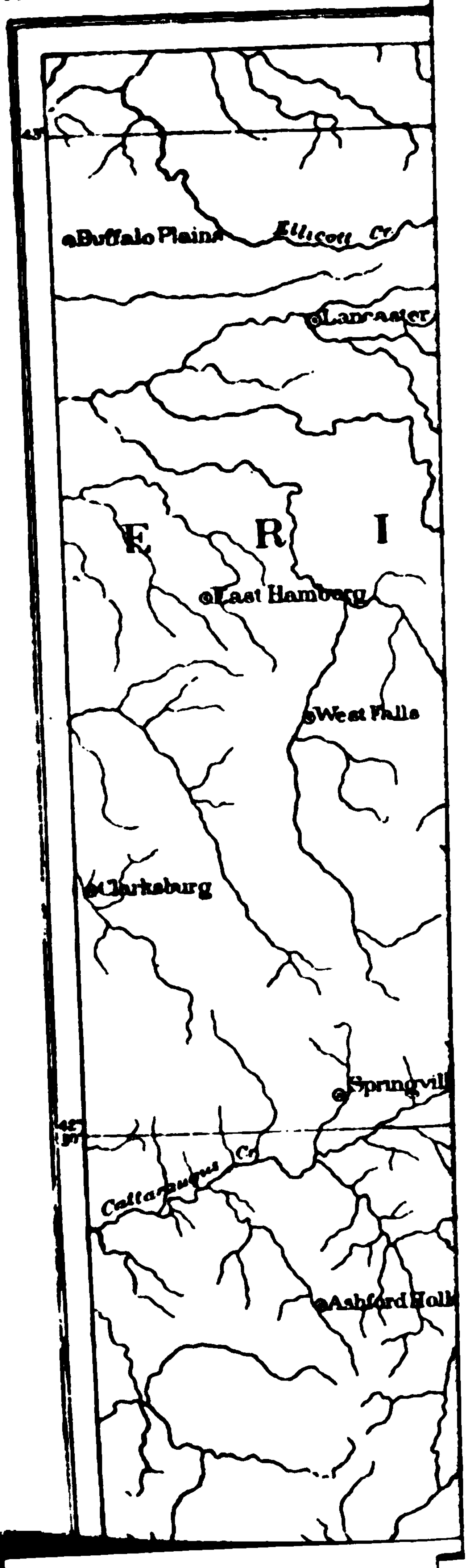

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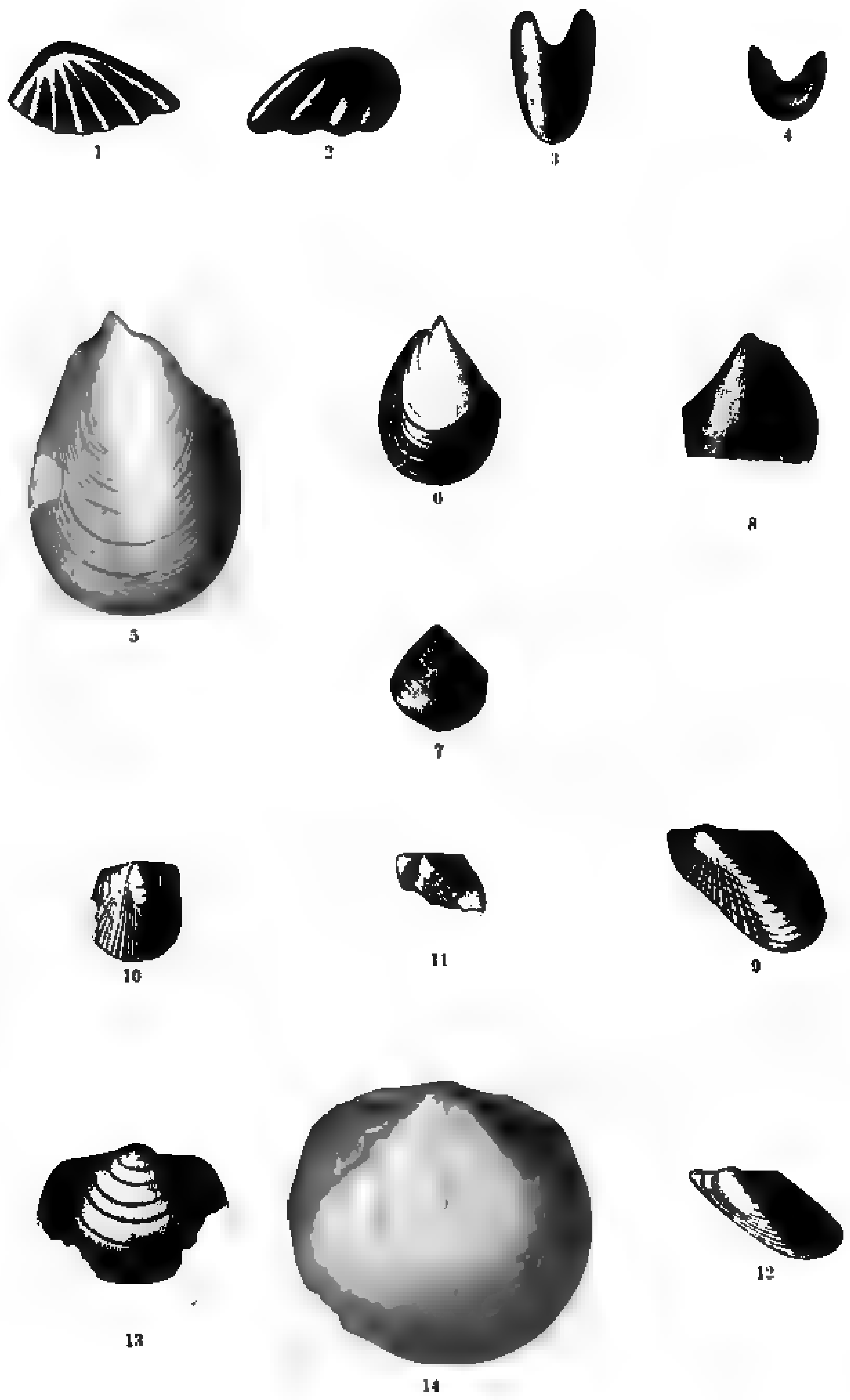

UPPER DEVONIAN LAMELLIBRANCHS, ETC.

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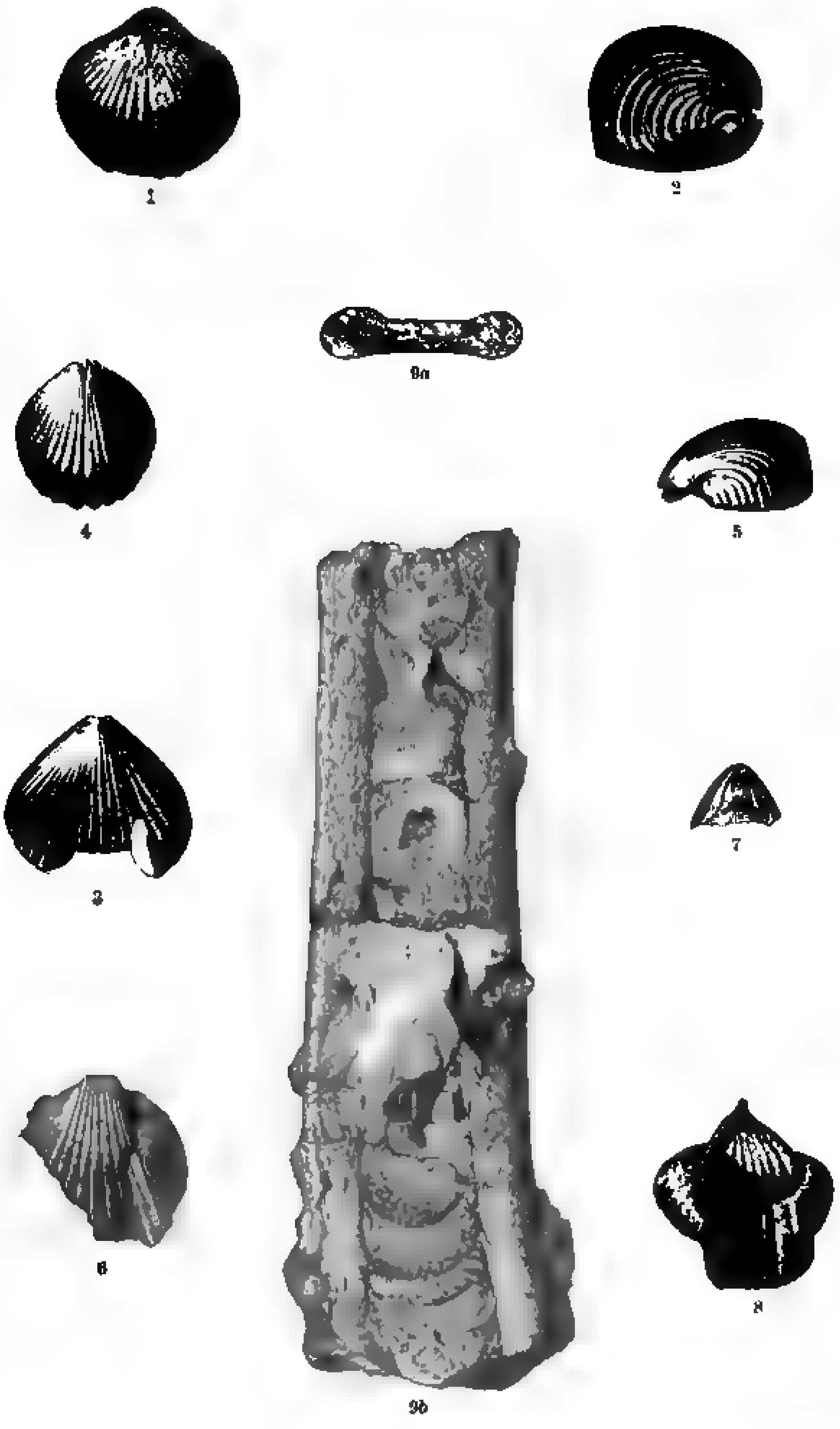

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DEPARTMENT OF THE INTERIOR

BULLETINS

OF THE

UNITED STATES

GEOLOGICAL SURVEY

VOL. VI

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

CONTENTS.

ILLUSTRATIONS.

BULLETIN No. 37.

NOTICE.

The bulletins of the United States Geological Survey are numbered in a continuous series and will be bound in volumes of convenient size.

This bulletin will be included in Volume VI.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 42

REPORT OF WORK DONE IN THE DIVISION OF CHEMISTRY
AND PHYSICS MAINLY DURING THE FISCAL YEAR 1885-'86

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

ADVERTISEMENT.

[Bulletin No. 42.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Second Annual Report of the United States Geological Survey, 1880-'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881-'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882-'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883-'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

VI. Sixth Annual Report of the United States Geological Survey, 1884-'85, by J. W. Powell. 1886. 8°. xxix, 570 pp. 65 pl. and maps.

The Seventh and Eighth Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, IX, X, XI, and XII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-Bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

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In preparation:

— The Glacial Lake Agassiz, by Warren Upham.
— Notes on the Geology of Southwestern Kansas, by Robert Hay.
— On the Glacial Boundary, by G. F. Wright.
— Geology of the Island of Nantucket, by N. S. Shaler.
— Author Catalogue of Contributions to North American Geology, 1790–1886, by Nelson H. Darton.
— The Gabbros and Associated Rocks in Delaware, by F. D. Chester.
— Report on the Geology of Louisiana and Texas, by Lawrence C. Johnson.
— Fossil Woods and Lignites of the Potomac Formation, by F. H. Knowlton.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

In press:

— Mineral Resources of the United States, 1886, by David T. Day. 1887. 8°.

Correspondence relating to the publications of the Survey and all remittances (which must be by POSTAL NOTE or MONEY ORDER, not stamps) should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *November 30, 1887.*

DEPARTMENT OF THE INTERIOR

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OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 42

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1887

[redacted]

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

REPORT OF WORK DONE

IN THE

DIVISION OF CHEMISTRY AND PHYSICS

MAINLY DURING THE

FISCAL YEAR 1885-'86

F. W. CLARKE, Chief Chemist

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

CONTENTS.

ILLUSTRATIONS.

PREFACE.

The present bulletin, like the preceding bulletins numbered 9 and 27, is intended to give a fair representation of the work done in the chemical and physical laboratories of the United States Geological Survey during one fiscal year. It covers, however, only such work as has been actually finished during the stated time, and therefore much material relative to investigations still in progress has been necessarily omitted. One paper, like two others in Bulletin 27, represents the continued co-operation of Prof. V. Strouhal, of Prague, and another bears the names of F. W. Clarke and J. S. Diller as joint authors. Although Mr. Diller is connected with another branch of the Survey, he has rendered many services to this division and has added much to the value of two of the papers herein presented.

The two papers by Dr. Gooch cover investigations which were necessary in the course of a large series of analyses of geyser waters from the Yellowstone Park. The latter are held back for the present, but will appear in a future publication. Mr. Whitfield's research also arose out of similar exigencies. In each case the existing methods of determination were unsatisfactory and not exact enough for our purposes.

F. W. CLARKE,
Chief Chemist.

MAP OF A PORTION OF WESTERN MAINE

WORK DONE IN THE DIVISION OF CHEMISTRY AND PHYSICS IN 1885–'86.

SCIENTIFIC PAPERS.

RESEARCHES ON THE LITHIA MICAS.

By F. W. Clarke.

I. THE LEPIDOLITES OF MAINE.

In the western part of Maine, along a line running southeasterly from the Rangeley Lakes to a point on the seaboard between Portland and Brunswick, is a series of veins of albitic granite which are noted for the lithia micas and colored tourmalines that they contain. These localities, in the towns of Hebron, Auburn, Norway, Paris, and Rumford, are all within a narrow belt of about 40 miles in length, and with them, as a probable part of the same system, may be classed the spodumene locality in the town of Peru. The northernmost locality is that on Black Mountain, in Rumford; but a few fragments of inferior green tourmaline have been found about five or six miles farther north, in Roxbury, a fact which indicates a prolongation of the belt in that direction. Similarly, a southern extension of the belt is suggested in the region covered by the towns of Pownal, Durham, Yarmouth, and Freeport, a region from which a few specimens of lepidolite have been reported. The total width of the belt, so far as has been observed, appears to be not much over 15 miles.

In general character the several localities are much alike, although in points of minor detail they differ considerably. With the tourmaline and lepidolite, quartz, muscovite, cleavelandite, cassiterite, and amblygonite are always associated; and other minerals, to be specially noted in the separate consideration of the localities, are often found. Some of the differences are doubtless due to the fact that certain localities have been more thoroughly opened up than others, and these would probably be eliminated by more complete exploration. Other differences, however, are notable and characteristic. The accompanying map (Plate I), which shows the geographical distribution of the localities, will be of use for reference during the following discussion.

For convenience we may consider the lepidolites of the several localities separately, beginning with the northernmost and proceeding southward in regular order.

Rumford.—The Rumford locality was discovered several years ago by Mr. E. M. Bailey, of Andover, Maine, but it was not opened up until 1883. It is most easily approached from Andover and is situated on the northern slope of Black Mountain, at an estimated elevation of about a thousand feet above the base. As yet the excavations are merely superficial, although they are sufficient to show the general character of the deposit. A part of the lepidolite, which is very abundant, is fairly pure, lilac purple in color, and finely granular; but the larger portion of the mineral is coarser in structure, reddish, and thickly sprinkled with small, opaque, red tourmalines. The color of the latter is very rich, and some are found in radiated masses of considerable size; but so far no true gem material has been obtained at the locality. The appearance of the associated lepidolite and tourmaline is strikingly characteristic and resembles nothing from the other localities of the region. Green tourmaline is found quite sparingly, and so also are amblygonite and tinstone. The spodumene, however, is one of the notable features of the deposit, occurring in masses of very great size. Faces of this mineral over a meter in length can be observed at several points along the vein. At the other lepidolite localities spodumene is comparatively scarce. An analysis of the granular purple lepidolite gave Mr. R. B. Riggs the following results:

	I	II
SiO_2	51.52	51.32
Al_2O_3	25.89	26.35
Fe_2O_3	.51	
FeO	Undet.	
MnO	.20	....
CaO	.16	....
MgO	.02	....
Li_2O	4.87	4.93
Na_2O	1.18	.94
K_2O	11.00	11.02
H_2O	.88	1.02
F	5.80	5.91
	101.83	
Less oxygen	2.44	
	99.39	

In the ordinary analysis no cæsium nor rubidium could be found; but a bare trace of the the latter was shown spectroscopically in an examination of the alkalies concentrated from 150 grammes of the mineral. In the analyses the water was determined directly by means of the

Gooch tubulated crucible. Lithia was estimated by the new method devised by Dr. Gooch and described in another part of this bulletin. The fluorine was determined by the old Berzelius process.

Paris.—The famous locality known as Mount Mica, which lies about a mile eastward from the village of Paris, was discovered in 1820 by Messrs. E. L. Hamlin and Ezekiel Holmes. Since that time large excavations have been made in search of mica and of gem tourmalines, and the locality is one of those most noted among mineral collectors. It has been thoroughly described by various writers, especially by Dr. A. C. Hamlin in his little book The Tourmaline.[1] Quite naturally, on account of the long continued explorations, the list of species found at Mount Mica is much fuller than that for any of the other deposits; and, according to Mr. S. R. Carter, who has supervised much of the excavation and made large personal collections, it embraces the following minerals: *Tourmaline*, black, green, red, blue, white, and yellow; *Beryl*, green, white, and yellow; *Quartz*, rose, yellow, smoky, and crystallized; *Garnet; Zircon; Albite*, cleavelandite; *Orthoclase; Spodumene; Muscovite; Biotite; Lepidolite; Autunite; Apatite*, green, blue, and crystallized; *Cookeite; Brookite; Childrenite; Yttrocerite; Amblygonite; Kaolinite; Halloysite; Cassiterite; Lölingite; Triphylite; Pyrite;* and *Tantalite* (?).

The lepidolite occurs both in the purple, granular form, and also broadly foliated like muscovite. The latter variety was analyzed by Mr. Riggs, and the results may well be compared with those obtained by Berwerth[2] and by Rammelsberg:[3]

	Riggs.		Berwerth.	Rammelsberg.
	I.	II.		
SiO_2	50.92	50.68	50.39	52.61
Al_2O_3	24.99	....	28.19	28.43
Fe_2O_3	.30	....	....	....
FeO	.23	....	....	....
MnO	Trace	....	Trace	Mn_2O_3 Trace
Li_2O	4.11	4.29	5.08	4.09
Na_2O	2.23	2.00	....	.79
K_2O	11.50	11.25	12.34	10.89
Cs_2O	Trace	....	....	....
Rb_2O	Trace	....	....	....
H_2O	1.92	2.00	2.36	.22
F	6.29	6.31	5.15	5.19
	102.49		103.51	102.22
Less oxygen	2.64		2.17	2.19
	99.85		101.34	100.03

[1] Published by James R. Osgood & Company, Boston, 1873, 12°, 107 pp.
[2] Zeit. Kryst. Min., 2, p. 523.
[3] See Third Supplement to Dana's System of Mineralogy p. 79.

…n only were present these would g… …ing proportions of the two metals:

	I.	II.
	11.47	11.40
	.88	.66
	12.35	12.06

…esent, therefore, must be less than the fig-…

…ron lepidolite there have been found speci-… …urmaline, which, preserving their crystalline… …teration into a softer mineral of an opaque,… …e of this material so derived from tourmaline… …lepidolite; and, as it was possible that a study… …r. an analysis of a pink specimen, originally rub-… …Riggs. The specific gravity, as determined by… …2.87. Analysis is as follows:

	43.90
	38.71
	.58
	.25
	.04
	.41
	.06
	1.05
	10.92
	4.25
	None
	Strong trace
	100.16

…show clearly that the alteration product is not lepido-… …ite, a fact which could hardly be altogether unexpected. …he western part of this town, near the Minot line, there… …less than half a mile apart, yielding lepidolite with the… …ls. The one longest known is small and apparently un-… …he other, lying about southeast of the first, upon the… Hatch, has been thoroughly opened. It has yielded… gem tourmalines, mostly of the paler greenish, lilac,… …, unusually fine crystallizations of apatite, and per-… …stallizations of lepidolite so far known.[1] Cookeite,… …assiterite, muscovite, biotite, beryl, garnet, quartz…

[1] …is locality, see G. F. Kunz, Am. Jour. Sci. (3…

Hebron.—About 7 miles southeast of Mount Mica is the well known locality in Hebron, which, however, because of legal complications in the title to the land, has been but little worked. All the exploration, so far, has been superficial; and yet many fine specimens of green and red tourmaline, cassiterite, amblygonite, cookeite, beryl, apatite, and childrenite have been obtained. The lepidolite of this locality is of the ordinary purple, coarsely granular kind, but is especially interesting on account of the fact that it has supplied chemists with considerable quantities of the rare metals cæsium and rubidium. The existence of these elements in lepidolite was first pointed out by Johnson and Allen,[1] who were working on the Hebron mineral; and yet no complete analysis of the latter seems so far to have been published.

The following results were obtained by Mr. Riggs:

	I.	II.
SiO_2	48.80	48.68
Al_2O_3	28.29	28.71 (Al_2O_3, Fe_2O_3, FeO)
Fe_2O_3	.29	
FeO	.09	
MnO	.08	....
CaO	.10	....
MgO	.07	....
Li_2O	4.40	4.58
Na_2O	.72	.76
K_2O, Rb_2O, Cs_2O	12.35	12.06
H_2O	1.66	1.80
F	4.96	5.19
	101.81	
Less oxygen	2.02	
	99.79	

In this case the potassium, rubidium, and cæsium were weighed together as chlorides and the chlorine was subsequently determined. The percentages given, 12.35 and 12.06, respectively, therefore represent the actual oxides present, and not merely a computation of all as potash from the platinchloride. In the one case we have 10.34 of metal to 2.01 of oxygen, while in the second analysis we have the ratio 10.98

[1] Am. Jour. Sci. (II), XXXV, p. 94.

to 1.98. If cæsium and potassium only were present these would give by indirect calculation the following proportions of the two metals:

	I.	II.
K_2O	11.47	11.40
Cs_2O	.88	.66
	12.35	12.06

The cæsia and rubidia present, therefore, must be less than the figures given for Cs_2O.

Associated with the Hebron lepidolite there have been found specimens of red and green tourmaline, which, preserving their crystalline form, have undergone alteration into a softer mineral of an opaque, talcose appearance. Some of this material so derived from tourmaline has been supposed to be lepidolite; and, as it was possible that a study of it might be of interest, an analysis of a pink specimen, originally rubellite, was made by Mr. Riggs. The specific gravity, as determined by Mr. T. M. Chatard, was 2.87. Analysis is as follows:

SiO_2	43.90
Al_2O_3	38.71
Fe_2O_3	.58
FeO	.25
MnO	.04
CaO	.41
MgO	.05
Na_2O	1.05
K_2O	10.92
H_2O	4.25
F	None
B_2O_3	Strong trace
	100.16

These results show clearly that the alteration product is not lepidolite, but damourite, a fact which could hardly be altogether unexpected.

Auburn.—In the western part of this town, near the Minot line, there are two localities, less than half a mile apart, yielding lepidolite with the associated minerals. The one longest known is small and apparently unimportant, while the other, lying about southeast of the first, upon the farm of Mr. G. C. Hatch, has been thoroughly opened. It has yielded a large number of gem tourmalines, mostly of the paler greenish, lilac, or lavender colors, unusually fine crystallizations of apatite, and perhaps the best crystallizations of lepidolite so far known.[1] Cookeite, orthoclase, albite, cassiterite, muscovite, biotite, beryl, garnet, quartz,

[1] For a description of this locality, see G. F. Kunz, Am. Jour. Sci. (III), XXVII, p. 303.

and amblygonite are among the other species here found. The lepidolite occurs in the ordinary purple, coarsely granular form, and also in remarkable perfection as a border upon muscovite, the broad plates of the latter being practically encircled by aggregations of small crystals of the lithia mica. Some specimens of this type have also been found at Paris, but the Auburn examples are much finer than those from other localities. The accompanying illustration (Fig. 1) shows the peculiar association of the two minerals.

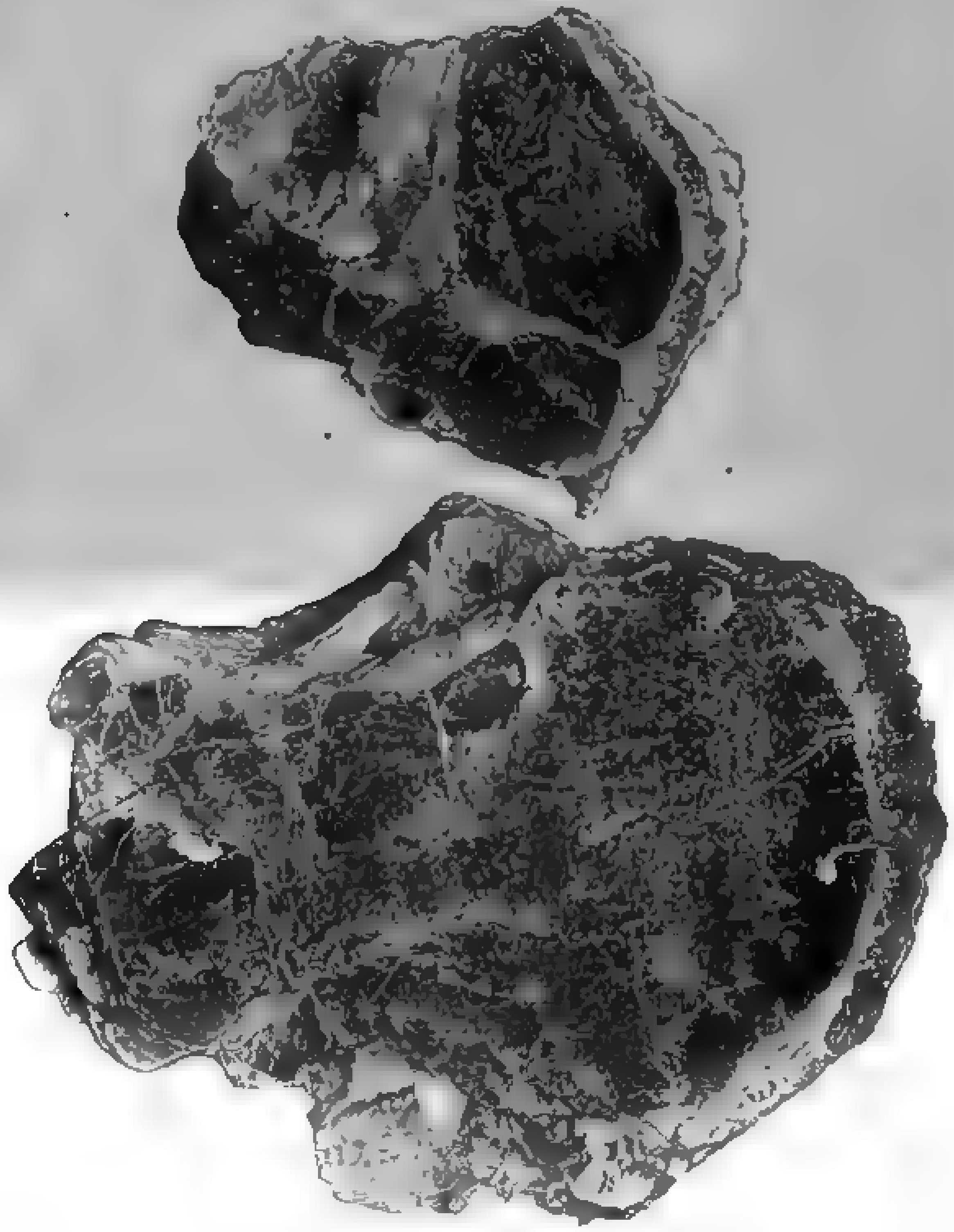


FIG. 1. Border of lepidolite on muscovite.

As it was hoped that this mode of occurrence of lepidolite might throw some light upon its genesis, three analyses of material from Auburn were made by Mr. Riggs: first, of the common granular variety; secondly, of the border upon muscovite; and, thirdly, of the muscovite itself from the center of the second specimen. The results were as follows, the lithia being determined by the old phosphate method:

	I. Granular lepidolite.			II. Border on muscovite.		III. Muscovite.
SiO_2	51.11			49.62		44.48
Al_2O_3	25.26			27.20		35.70
Fe_2O_3	.20			.31		1.09
FeO	.07			.07		1.07
MnO	.17			.55		Trace
CaO	.12			....		.10
MgO	.01			....		Trace
Li_2O	4.78	5.17		4.50	4.17	Trace
Na_2O	1.52	1.35		2.10	2.25	2.41
K_2O	10.51 }			8.03		9.77
Rb_2O	1.29 }	12.21		2.44		....
Cs_2O	.45 }			.72		....
H_2O	.88	1.01		1.52		5.50
F	6.57	6.67	6.60	5.45	5.78	.72
	102.94			102.51		100.84
Less oxygen	2.76			2.29		.30
	100.18			100.22		100.54

In these analyses the determinations of cæsia and rubidia are to be considered merely as rough approximations. The cæsium was separated as stannichloride, and the rubidium and potassium were computed from the amount of chlorine in the mixed chlorides of the two metals. In the oxides K_2O, Rb_2O, and Cs_2O, taken together, the actual ratio of metal to oxygen in analyses I and II is as follows:

	I.		II.
Metal	10.32	10.26	9.57
Oxygen	1.93	1.95	1.62
$(KRbCs)_2O$	12.25	12.21	11.19

Norway.—This locality, which has been but little opened, is about seven miles from Mount Mica, in a southerly direction. With the lepidolite are associated, as usual, quartz, the feldspars, the micas, cassiterite, lithiophilite, beryl, &c., and also a peculiar rose red clay, derived from some other species by alteration. Most of the colored tourmaline is of a peculiar dark oily green tint, and the lepidolite is partly of a coarsely granular white variety and partly of a brownish, very finely granular sort.

Analyses of both varieties by Mr. Riggs came out as follows:

	White.		Brown.
SiO_2	49.52	49.45	50.17
Al_2O_3	28.80		25.40
Fe_2O_3	.40		.87
FeO	24		.45
MnO	.07		.23
CaO	.13		Undet.
MgO	.02		Undet.
Li_2O	3.87		4.03
Na_2O	.13		
K_2O	8.82	12.70	13.40
Rb_2O	3.73		
Cs_2O	.08		
H_2O	1.60	1.85	2.02
F	5.18	5.39	5.05
	102.59		101.62
Less oxygen	2.18		2.13
	100.41		99.49

The analysis of the brown variety was only partial.

The lithia was determined by the phosphate method, while, as in the case of the Auburn material, the cæsia and rubidia estimations are merely approximative. The actual ratios between metal and oxygen in the potassium group, as found in the two experiments upon the white lepidolite, are subjoined:

Metal	10.83	10.91
Oxygen	1.80	1.79
$(KRbCs)_2O$	12.63	12.70

The fact that this lepidolite is the richest of the series in these rare metals becomes doubly interesting when we remember that a beryl from the same or a nearly adjacent locality gave Penfield 1.66 per cent. of cæsia.[1]

Of the rose-red clay, previously mentioned, a partial analysis was published in Bulletin No. 9, U. S. Geol. Surv. The following complete analysis by Mr. Riggs is better, and shows, in spite of some little non-uniformity of composition in the material, that it is to be classed most definitely as cimolite:

SiO_2	66.86
Al_2O_3	22.23
Fe_2O_3	.47

[1] Am. Jour. Sci. (III), XXV, p. 28. The Hebron beryl contains 2.92 per cent.

FeO	.18
MnO	.07
CaO	.42
MgO	.33
Li_2O	.29
Na_2O	.46
K_2O	.18
H_2O	8.26
F	.06
	99.81
Less oxygen	.02
	99.79

Formula, $Al_2H_4(SiO_3)_5$.

It is not easy to determine, from the specimens at hand, from what species this clay has been derived.

DISCUSSION OF RESULTS.

The foregoing analyses of the Maine lepidolites cover several distinct types of the mineral from five different localities, and yet they indicate a very great constancy or uniformity of composition. For convenience of comparison, we may tabulate the results, using mean values whenever two determinations of a constituent have been made. Two exceptions to this rule, however, have been adopted, namely, to use the higher determinations for silica and the lower for fluorine, because of the known direction of the experimental errors in the analytical processes. Slight loss of silica, when fluorine is present, is difficult to avoid; and so also slight impurities in the calcium fluoride can hardly be eliminated. With these qualifications the analyses may be stated as follows:

	Rumford, purple.	Paris, foliated.	Hebron, granular.	Auburn.		Norway.	
				Border.	Granular.	White.	Brown.
SiO_2	51.52	50.92	48.80	49.62	51.11	49.52	50.17
Al_2O_3	25.96	24.99	28.30	27.30	25.26	28.80	25.40
Fe_2O_3	.31	.30	.29	.31	.20	.40	.87
FeO	Undet.	.23	.09	.07	.07	.24	.45
MnO	.20	Trace	.08	.55	.17	.07	.23
CaO	.16	Trace	.10	....	.12	.13	Undet.
MgO	.02	Trace	.07	....	.01	.02	Undet.
Li_2O	4.90	4.20	4.49	4.34	4.98	3.87	4.03
Na_2O	1.06	2.11	.74	2.17	1.43	.13	
K_2O	11.01	11.38		8.03	10.51	8.82	13.40
Rb_2O	....	Trace	12.21	2.44	1.29	3.73	
Cs_2O	....	Trace		.72	.45	.08	
H_2O	.95	1.96	1.73	1.52	.94	1.72	2.02
F	5.80	6.29	4.96	5.45	6.57	5.18	5.05
	101.89	102.38	101.86	102.52	103.11	102.71	101.62
Less oxygen	2.44	2.64	2.02	2.29	2.76	2.18	2.13
	99.45	99.74	99.84	100.23	100.35	100.58	99.49

With this table may be advantageously compared the following analyses of lepidolite from three foreign localities:[1]

	Rozena.		Cornwall, Rammelsberg.	Juschakova.	
	Berwerth.	Rammelsberg.		Roesler.	Rammelsberg.
SiO_2	50.98	51.32	51.70	48.92	50.26
Al_2O_3	27.80	26.00	26.76	19.03	21.47
Fe_2O_3	....	....	....	....	....
FeO	.06	....	....	....	....
Mn_2O_3	....	1.30	1.29	5.50	5.36
CaO	....	....	.40	.14	....
MgO	....	....	.24	....	....
Li_2O	5.88	3.87	1.27	2.77	4.82
Na_2O	....	.96	1.15	2.23	.54
K_2O	10.78	9.86	10.29	10.96	11.08
H_2O	.96	.57	....	....	.88
F	7.68	7.18	7.12	10.44	8.71
Cl	....	....	....	1.31	1.16
P_2O_5	.05	....	.16	....	....
	104.38	101.18	100.38	101.39	104.12
Less oxygen	3.37	3.02	2.99	4.68	3.92
	101.01	98.16	97.39	96.71	100.19

Few other lepidolite analyses are worth quoting, except possibly Cooper's analysis of the Rozena mineral, in which he found 0.24 per cent. of rubidia and a trace of cæsia.[2] The essential identity of the material from Maine, Rozena, and Cornwall is thus made clear, while the lepidolite from Juschakova is different in its large percentage of manganese, its higher fluorine, and its trace of chlorine. In the last named mineral of course the manganese replaces an equivalent amount of alumina, and the function of chlorine is the same as that of fluorine. In the other analyses, to speak in general terms, the water and fluorine vary somewhat reciprocally, suggesting the ordinary replacement of the latter element by hydroxyl. With this assumption, if it may be called so, the formula of lepidolite may be written thus:

$$Al_2(SiO_3)_3F_2LiK;$$

a formula which has long had general acceptance, but which is now put upon a surer basis by the wider range of analyses. It corresponds to the following theoretical composition:

Calculated.			Found (Riggs).
SiO_2	49.18	SiO_2	48.80 to 51.52
Al_2O_3	27.87	Al_2O_3	24.99 to 28.80
Li_2O	4.09	Li_2O	3.87 to 4.98
K_2O	12.81	$(NaKRbC_s)_2O$	12.07 to 13.68
F	9.84	(F,H_2O)	6.69 to 8.25

[1] See Dana's System of Mineralogy, p. 315, and Third Supplement, pp. 78, 79.
[2] *Pogg.* Ann., pp. 113, 343.

Most of the variations from theory are no greater than we should expect to find them with material so difficult to secure in absolute purity as lepidolite. The granular structure of the species is peculiarly favorable to the presence of inclusions of foreign matter, such as albite, for example, to which latter impurity some of the soda found in the analyses is very probably due. The greatest difference is in the case of fluorine, although the foreign analyses—notably Rammelsberg's analysis of the Juschakova mineral—contain very nearly the full theoretical amount. If, however, the fluorine is present in the univalent group AlF_2, it is possibly replaceable in part by the similar group AlO, a supposition which easily accounts for all the variations. With this supposition it becomes a simple matter to write a probable structural formula for lepidolite, as follows:

$$Al\begin{cases} SiO_3-Al=F_2. \\ SiO_3-K. \\ SiO_3-Li. \end{cases}$$

Thus the mineral is regarded as a definite substitution derivative of the normal aluminum metasilicate $Al_2(SiO_3)_3$, one atom of Al having been replaced by the three univalent factors represented above. Another view of its structure is given at the close of this paper.

II. THE IRON LITHIA MICAS OF CAPE ANN.

In the granite quarries of Rockport, Massachusetts, near the extremity of Cape Ann, there are occasional veins of feldspathic character which contain, along with the ordinary constituents of such veins, the rare minerals danalite, fergusonite, cyrtolite, amazon stone, and certain remarkable micas. One of the latter, cryophyllite, was described by Cooke in 1867,[1] who also analyzed an associated "lepidomelane," to which Dana afterwards gave the name of annite. The vein from which Cooke obtained his material was long ago blasted away or covered up, but other veins of like nature are still accessible, and from one of them the micas examined in this laboratory were obtained. They were collected for the United States National Museum by the original discoverer of the locality, Mr. W. J. Knowlton, and were, to all outward appearance, identical with the micas described by Cooke. The analyses, however, reveal notable differences between the older and the newer material and add great interest to the micas of the locality.

In the collection furnished by Mr. Knowlton two micas were clearly recognizable, the one a dark greenish black lithia mica, presumably cryophyllite, and the other a black, brilliant lepidomelane. In some specimens the cryophyllite formed a border of small crystals around the broader plates of annite, precisely as in the association of lepidolite and

[1]Am. Jour. Sci. (II), XLIII, p. 217.

muscovite at Auburn. The resemblance in this point is curiously striking, only that the Rockport specimens are less conspicuous than those from Auburn, since they lack the contrast of color by which the latter are characterized.

The lithia mica, or cryophyllite, varies considerably in external character, and three well marked types of it were selected for analysis: first, the broadly foliated, brilliant, blackish green mica, which showed no trace of alteration; secondly, a paler, dull green, less lustrous variety, apparently somewhat altered upon the surface; thirdly, an aggregation of minute six-sided prisms, so small as to give the mineral an almost granular appearance, similar to an ordinary dark green chlorite. The analyses were made by Mr. Riggs, who used the Gooch process for separating lithia and Berzelius's method for the fluorine. The results were as follows:

	Foliated.		Altered.		Granular.	
SiO_2	51.96	51.74	51.46	51.35	52.17	52.07
Al_2O_3	16.89		16.22		16.39	
Fe_2O_3	2.63		2.21		4.11	
FeO	6.35	6.20	7.66	7.60	6.08	5.90
MnO	.24		.06		.32	
CaO	.12		Trace		Trace	
MgO	.03		.17		Trace	
Li_2O	4.93	4.80	4.83	4.78	5.03	4.95
Na_2O	.92	.81	.95	.82	.60	.66
K_2O	10.66	10.73	10.65	10.65	10.54	10.42
H_2O	1.22	1.40	1.06	1.18	1.43	1.48
F	6.78	6.86	7.44	7.60	7.02	7.20
	102.73		102.71		103.69	
Less oxygen	2.86		3.11		2.95	
	99.87		99.60		100.74	

These results demonstrate the essential identity of the three specimens, but do not sharply correspond with the figures given by Cooke. In mean, using, as in the case of the lepidolites, the maximum silica and minimum fluorine determinations, they may be compared with Cooke's analysis as follows:

	Riggs.	Cooke.
SiO_2	51.86	51.49(+1.97)
Al_2O_3	16.50	16.77
Fe_2O_3	2.98	1.97
FeO	6.65	7.98
MnO	.21	Mn_2O_3 .34
CaO	.04	....
MgO	.07	.76
Li_2O	4.89	4.06
Na_2O	.79	Trace
K_2O	10.61	13.15. Tr. Rb_2O
H_2O	1.29	....
F	7.08	SiF_4 3.42. F, 2.49
	102.97	99.94
Less oxygen	2.98	
	99.99	

It will be seen at once that Cooke's mineral contains only about one-third of the fluorine found in the later analyses and that it runs notably higher in silica and alkalies. In general terms the same mineral is represented by both analyses, with the presumption as to purity in favor of the specimens examined by myself. If we assume that Cooke's material contained a slight isomorphous admixture of some other micaceous species poor in fluorine, the most important difference is accounted for.

Inasmuch as some writers have been inclined to identify cryophyllite with zinnwaldite, a comparison of the two species may be instructive. The published analyses of zinnwaldite vary widely, especially in the amounts of iron; but the older figures are subject to doubt as regards the relative proportions of ferrous and ferric oxides. Two comparatively recent analyses by Berwerth and Rammelsberg, however, agree fairly well with each other, although, compared with former determinations, they run low in iron. The comparison between the analyses is subjoined:

	Cryophyllite, Riggs.	Zinnwaldite.	
		Berwarth.[1]	Rammelsberg.[2]
SiO_2	51.86	45.87	46.44
Al_2O_3	16.50	22.50	21.84
Fe_2O_3	2.98	.66	1.27
FeO	6.65	11.61	10.19
MnO	.21	1.75	1.57
CaO	.04		
MgO	.07		.18
Li_2O	4.89	3.28	3.36
Na_2O	.79	.42	.54
K_2O	10.61	10.46	10.58
H_2O	1.29	.91	1.04
F	7.08	7.94	7.62
P_2O_5		.08	
	102.97	105.48	104.63

[1] Zeit. Kryst. und Min., II, p. 525. [2] See Third Supp. to Dana's Syst. Min., p. 79.

Reduced to empirical formulæ these analyses give two quite different ratios, which, however, do not admit of very simple expression:

Cryophyllite: $FeH_3K_3Li_4Al_4F_4(SiO_3)_{10}$;
or, $Al_2(SiO_3)_5F_2R'_6$.
Zinnwaldite: $Fe_3H_2K_4Li_4Al_8F_8(SiO_3)_{14}$;
or, $Al_4(SiO_3)_7F_4R'_8$.

The further consideration of these formulæ may be deferred until the latter portion of the paper. For present purposes they serve to show the non-identity of the two minerals.

For the lepidomelane, or annite, of Rockport, quite unexpected results were obtained. The material analyzed by Mr. Riggs was black, brilliant, broadly foliated, and apparently very pure. Upon the specimens examined some purple fluorite was visible. The water estimations were directly made with the Gooch tubulated crucible.

	Annite.		
	Riggs.	Cooke.	
SiO_2	31.96		39.55
TiO_2	3.42		......
Al_2O_3	11.93		16.73
Fe_2O_3	8.06		12.07
FeO	30.35		17.48
MnO	.21	Mn_3O_4	.60
CaO	.23		......
MgO	.05		.62
Li_2O	Trace		.59
Na_2O	1.54		Trace
K_2O	8.46		10.66
H_2O	4.25		1.50
F	Trace	SiF_4	.62
	100.46		100.42

It is at once evident that two entirely distinct micas are here represented, and the question is raised as to whether the Rockport granites may not contain a series of complex isomorphous mixtures. Cooke, indeed, pointed out the isomorphism of cryophyllite with the lepidomelane which he had analyzed, and showed that the lithia and the fluorine in the latter were probably due to admixtures of the former. We now see that more than two micas are involved in the problem, and the difficulty of establishing accurate formulæ for the several species becomes enormously increased. For the present, approximate formulæ only can be assigned, involving various assumptions and representing probabilities rather than complete interpretations of the facts. If we unite the groups TiO_2 and SiO_2 in our annite and regard the ferric iron as belonging partly with the alumina and as partly having been the result of oxidation from the ferrous state, we have the two following general formulæ for the two analyses:

Annite, Cooke, $R'_8Al_4(SiO_4)_5$.
Annite, Riggs, $R'_{14}Al_2(SiO_4)_5$.

For the latter, the equivalent of R' is approximately $K_2H_4Fe''_4$; and for the former it is $K_2H_2\,Fe''_2$. These values correspond to the following percentage compositions:

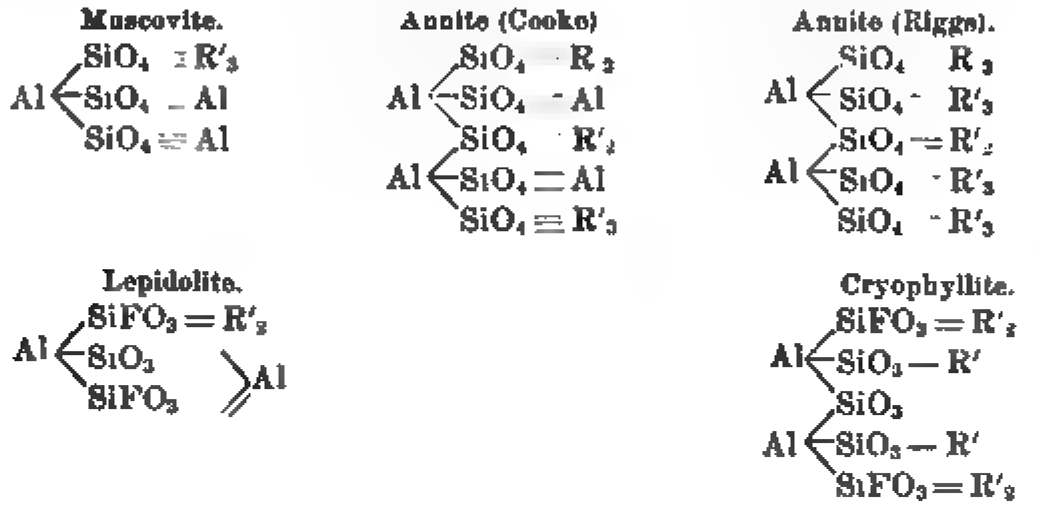
	Cooke.	Riggs.
SiO_2	39.5	36.6
Al_2O_3	26.8	12.4
FeO	18.9	35.1
K_2O	12.4	11.5
H_2O	2.4	4.4
	100.0	100.0

Attention has already been called to the fact that some specimens of cryophyllite are borders upon plates of annite, precisely as the lepidolite of Auburn is arranged about nuclei of muscovite. It accordingly becomes quite probable that a similar relation connects the two pairs of minerals, and upon that relation the formulæ so far assigned shed some light. In each case we have a mineral with metasilicate ratios implanted upon an orthosilicate, and a derivability of the one from the other is strikingly suggested. Structural analogies also appear, for in each pair we have a common type of nucleus, which may be represented as follows:

Muscovite nucleus, $Al(SiO_4)_3$. Annite nucleus, $Al_2(SiO_4)_6$.
Lepidolite nucleus, $Al(SiO_3)_3$. Cryophyllite nucleus, $Al_2(SiO_3)_6$.

The development of complete structural formulæ from these nuclei is rendered difficult by our ignorance of the part which fluorine plays in such compounds. In the formula previously assigned to lepidolite the fluorine is represented as combined with aluminum in the univalent group AlF_2; but a similar representation becomes difficult, if not impossible, in the case of the two iron micas. A different solution of the problem must therefore be sought, and it probably is to be found by an application of the generally recognized principle that fluorine and hydroxyl can replace each other isomorphously.

If, now, we start with orthosilicic acid $Si(OH)_4$ and regard the hydroxyl groups as successively replaceable by atoms of fluorine, we can conceive of a series of acids ranging from $Si(OH)_4$ to SiF_4; and by the aid of such a supposition many of the fluoriferous silicates may be rationally explained. For example, the acid $SiF(OH)_3$ may be considered, and its nucleus $SiFO_3$, a trivalent residue, may be applied to the discussion of the lithia micas. Upon this supposition the empirical formula for cryophyllite, $Al_2F_2Si_5O_{15}R'_6$, and the similar formula for lepidolite, $Al_2F_2Si_3O_9R'_3$, become curiously significant, especially when they are written out in contrast with two other formulæ, as in the subjoined scheme:



To the zinnwaldite, as represented by the newer analyses, no probable structure is assignable, and it is very possibly a mixture of isomor-

phous species. Indeed, the old analyses indicate great variability in its composition, and it needs to be more thoroughly studied, not only for itself, but also in its relations to whatever other micas may be associated with it. The matter of association can never, in the study of the micas, be safely neglected.

Although the formulæ herein assigned to annite and cryophyllite are purely provisional and approximative, at least as regards the values ascribable to R′, it may be set down as practically certain that the ratios between the sesquioxides and the silica are correctly given. These ratios are the ratios of phlogopite, with which, therefore, rather than with the lepidomelanes and biotites, the Rockport micas are chemically to be classed. Zinnwaldite is already so classed by Tschermak and others, and cryophyllite falls easily into the same category. A typical phlogopite is fairly represented by the subjoined formula:

$$
\begin{array}{l}
\mathrm{Al} \begin{cases} SiFO_3 = Mg \\ SiO_4 \equiv MgH \\ SiO_4 = Mg \end{cases} \\
\mathrm{Al} \begin{cases} SiO_4 \equiv MgK \\ SiFO_3 = Mg \end{cases}
\end{array}
$$

THE MINERALS OF LITCHFIELD MAINE.

By F. W. Clarke.

In Kennebec County, Maine, along and near the boundary between the towns of Litchfield and West Gardiner, are scattered many bowlders of an elæolite rock. For many years these have yielded to collectors of minerals superb specimens of blue sodalite, yellow cancrinite, and zircon; but although the parent ledge appears at several points, it seems nowhere to have been opened. In addition to the minerals already mentioned, the bowlders contain albite, lepidomelane, a black mineral resembling columbite, a flesh colored mineral which has been called indiscriminately elæolite or cancrinite, and a massive alteration product known to local collectors under the provisional name of "white sodalite." Although specimens from the locality are widely distributed in cabinets, some of the minerals seem to have been but partially described; and I have therefore thought it worth while to study them somewhat closely. The supposed columbite I have not examined, for want of material; the zircon I have omitted, since it has been sufficiently studied by Gibbs;[1] but the sodalite and cancrinite, although they had been well analyzed by Whitney,[2] I have included in my investigation, for reasons which will appear below.

ELÆOLITE.

This species occurs abundantly in Litchfield and West Gardiner in characteristic, dark gray, cleavable masses of strong greasy luster. Since it is the typical mineral of its group and as I can find no published analysis of it from this locality, the following results may have value as a matter of record:

H_2O	.86
SiO_2	43.74
Al_2O_3	34.48
CaO	Trace
MgO	Trace
K_2O	4.55
Na_2O	16.62
	100.25

[1] Pogg. Ann., LXXI, 559.

[2] Pogg. Ann., LXX, 431.

The specimen analyzed contained minute inclusions of black mica, but not enough of them to notably affect its composition. The analysis agrees fairly well with the published analyses of elæolite from other places.

CANCRINITE.

This mineral is one of the most abundant and characteristic at the locality and varies considerably in appearance. Two analyses of it were made by Whitney, one of the yellow variety, the other of a greenish modification. I have myself seen nothing to answer to the latter description, but have selected three typical samples for investigation. They may be briefly described and indicated as follows:

A. Bright orange yellow, with strong luster and cleavage, transparent in thin fragments.

B. Dirty pale yellow, less lustrous, highly cleavable, also transparent in thin fragments.

C. Bright yellow, granular—the commonest variety.

For ease of comparison I have tabulated the analyses side by side with Whitney's, indicating his yellow cancrinite by D and his greenish variety by E. The carbonic acid determinations were made for me by Mr. R. B. Riggs, who used the Gooch tubulated crucible and collected the gas evolved directly in a potash bulb.

	A.	B.	C.	D.	E.
SiO_2	36.29	35.83	37.22	37.42	37.20
Al_2O_3	30.12	29.45	28.32	27.70	27.59
Mn_2O_3	Trace	Trace	Trace	.86	.27
Fe_2O_3	Trace	Trace	Trace		
CaO	4.27	5.12	4.40	3.91	5.26
Na_2O	19.56	19.33	19.43	20.98	20.46
K_2O	.18	.09	.18	.67	.55
MgO	....	....	.07	....	....
H_2O	2.98	3.79	3.86	2.82	3.28
CO_2	6.96	6.50	6.22	5.95	5.92
	100.36	100.11	99.70	100.31	100.58

It will at once be observed that cancrinite A, which, from its appearance, was presumably the purest type of the mineral, is the highest of my series in carbonic acid and the lowest in water. It is also the highest in soda and alumina. Whitney's two analyses show more potash than mine, but in other respects run fairly near C, which, as I have said, represents the commonest and probably the least pure variety. But, in order to understand the variations better, we must consider the flesh colored mineral referred to in my introductory paragraph, which, as I have said, has been called indiscriminately elæolite or cancrinite, according to the fancy of the collector. It sometimes occurs in specimens of considerable size, is lustrous and cleavable, and to the eye ap-

pears perfectly homogeneous. An analysis gave the following results, the carbonic acid, as in the other cases, being determined by Mr. Riggs:

SiO_2	38.93
Al_2O_3	32.52
CaO	2.47
Na_2O	17.02
K_2O	3.23
H_2O	2.83
CO_2	2.95
	99.95

These figures plainly indicate that the mineral is a mixture of elæolite and cancrinite, but do not show whether the mixture is mechanical or due to isomorphism. To determine this point, Mr. J. S. Diller kindly undertook a microscopic examination of the material, comparing it in thin sections with the elæolite and cancrinite B, from the specimens of which portions were previously analyzed. He found the mineral to be a merely mechanical commingling of the two species, in nearly equal proportions, and later he succeeded in separating them by means of Sonstadt's solution. This fact, considered together with the apparent homogeneity of the material, renders it probable that the variations in composition of the cancrinite are due to small admixtures of elæolite, and that Whitney's specimens were rather more so contaminated than mine. Still, the entire series of cancrinite analyses are fairly concordant and confirmatory of one another. In discussing the formula of the mineral, however, analysis A will be given preference.

SODALITE.

On account of its beauty and its intense blue color, this mineral, as it occurs at Litchfield, is a favorite among collectors. It is now somewhat scarce, at least in large or compact specimens, and it ought to be carefully searched for in place. It often occurs intermingled with cancrinite, forming beautifully mottled masses, and also is associated intimately with the white, massive alteration product to be described later. The following analysis was made partly for comparison with Whitney's and partly to aid in the study of the accompanying white mineral:

	Clarke.	Whitney.	
SiO_2	37.33	37.30	37.63
Al_2O_3	31.87	32.88	30.93
Fe_2O_3	....	......	1.08
Na_2O	24.56	23.86	23.48
K_2O	.10	.59	Undet.
Cl	6.83	6.97	Undet.
H_2O	1.07	....	....
	101.76	101.60	
Deduct O=Cl	1.54		
	100.22		

In my analysis iron was not looked for, because the ignited alumina, which should have contained it if present, was perfectly white. Otherwise the analyses agree tolerably well.

HYDRONEPHELITE, A NEW SPECIES.

Intimately associated with the sodalite is the white alteration product mentioned in the last paragraph. So close is the association in fact and so similar in occurrence are the two minerals that the latter has been called white sodalite by the local collectors. Like the sodalite it is found in seams, and yields specimens as much as two centimeters in thickness; it is white, lusterless, and has the fracture of sodalite, and probably it originated from the alteration of the latter. Two specimens of it, received from two different collectors, were analyzed, with the following results:

	A.	B.
H_2O	13.12	13.30
SiO_2	38.90	39.24
Al_2O_3	33.98	33.16
CaO	.05	Trace
Na_2O	13.21	13.07
K_2O	1.01	.88
Cl	Trace	....
	100.27	99.65

The alumina carried a trace of iron, and a doubtful trace of manganese was also indicated; hardness, 4.5; fusible easily to a white enamel; soluble in hydrochloric acid and gelatinizing upon evaporation; fracture irregular, resembling that of the sodalite. In general, the mineral may be said to have the appearance of a slightly altered feldspar, minus the distinct cleavage.

These analyses left little doubt in my mind that I had a new mineral to deal with, and one belonging to the zeolite family. Such minerals are well known derivatives of the nephelite group, and thomsonite and natrolite have especially been often noted. In composition the new product differs distinctly from natrolite, but agrees in ratios approximately with thomsonite; forming, so far as chemical evidence alone goes, the soda end of a series passing through rauite up to ozarkite, the last named mineral being the nearest towards the lime end of the series. A comparison of the analyses of these elæolite derivatives is worth making, on account of its suggestiveness. The ozarkite was analyzed by Smith and Brush; the rauite, from Brevig, by Paykull.[1]

[1] Ber. deutsch. chem. Gesell., VII, p. 1334.

	Ozarkite.	Ranite.	Hydro-nephelite.
H_2O	13.80	11.71	13.12
SiO_2	36.85	39.21	38.90
Al_2O_3	29.42	31.79	33.98
Fe_2O_3	1.55	.57	....
CaO	13.95	5.07	.05
Na_2O	3.91	11.55	13.21
K_2O	....	....	1.01
	99.48	99.90	100.27

Inasmuch, however, as massive minerals, and especially those which are produced by processes of alteration, are always subject to doubt, I requested Mr. Diller to assist me with a microscopic examination of the new substance. He very kindly acceded to my request, and I subjoin an abstract of his results. In his report on it he says:

"A section was carefully prepared so as to show both the sodalite and the white lusterless mineral associated with it in such a way as to reveal their relations. The accompanying figure illustrates a small portion of the section as seen under the microscope.

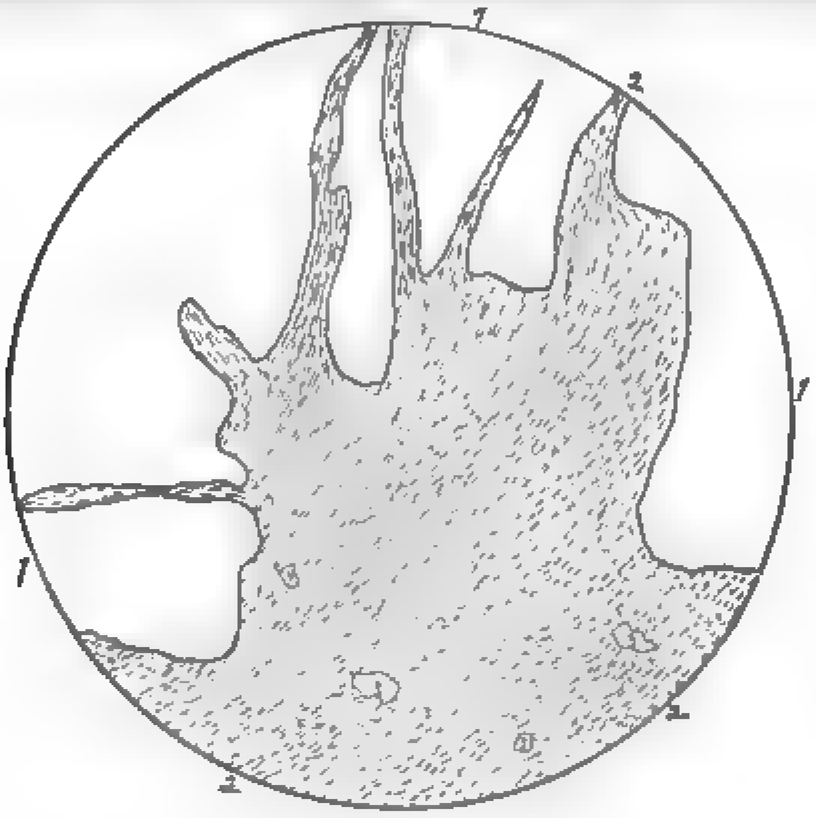


FIG. 2. Portion of thin section of hydronephelite.

"The unaltered sodalite (1) is quite irregular in form, so that the position of the section with reference to the crystallographic axes could not be determined. Although of a distinct, cobalt blue color in the small frag-

ment, it appears colorless and transparent in the thin section, and under the microscope it is seen to contain numerous liquid inclusions. It is penetrated by many irregular fissures, which are enlarged in the process of alteration and filled with its clouded products. The extremely irregular line between the sodalite and its secondary products is well defined in transmitted light, but is even more distinct between crossed nicols from the fact that the sodalite, being isotropic, remains dark in all positions, while the other minerals are more or less brilliantly colored. The secondary products, which have clearly resulted from the zeolitization of the sodalite, are two in number. One of them forms very much the larger portion, probably nearly 90 per cent. of their total amount, and the other is embedded in the first in the form of distinct grains. Under the microscope in transmitted light the predominating mineral, which is doubtless a zeolite as shown by your analyses, is more or less deeply clouded, like decomposed feldspar. Between crossed nicols it breaks up into flaky grains, which vary considerably in the intensity of their color; some remain dark, others range through light and medium tints of red and yellow, according to the position of the section. The isotropic grains in converging light are proved to be distinctly uniaxial and positive, and the anisotropic ones, so far as can be determined, exhibit parallel extinction. It is evident therefore that the zeolite must be either quadratic or hexagonal in the system of its crystallization. Some of the grains show an indistinct striation approximately parallel to the vertical axis, but a distinct cleavage could not be discerned. In basal sections three sets of fractures could be rarely made out with sufficient distinctness to suggest that the mineral is probably hexagonal. The mode of its occurrence indicates clearly that it has resulted from the zeolitization of the sodalite, a phenomenon which has been observed in many rocks. The small grains of the other secondary mineral are so intermingled with the uniaxial zeolite as to indicate that both are derived from the sodalite. They are easily distinguished from the zeolite in which they are embedded. In transmitted light they are perfectly clear and transparent, with so high an index of refraction as to appear to rise above the surrounding mass. The grains are entirely without crystallographic boundaries, but are traversed by distinct cleavage lines. Between crossed nicols they are much more brilliantly colored than the associated zeolite, and if the section is rotated they become dark when the cleavage lines make a prominent angle (15°–33°) with the principal sections of the prisms. The mineral is certainly biaxial, and in all probability belongs to one of the two inclined systems of crystallization, but its definite determination is not practicable under the circumstances."

In view of the presence of an impurity in the new zeolite, Mr. Diller suggested a reanalysis of it to be made on carefully purified material. The purification, by means of Sonstadt's solution, he kindly undertook, determining at the same time the specific gravity of the mineral. The

crude material gave him a sp. gr. of 2.263, while the zeolite was a little lighter and the embedded grains were a little heavier. After purification the coarsely powdered zeolite was carefully picked over under the microscope until Mr. Diller felt confident that the sum of all impurities could not exceed 1 per cent. The mineral, then dried at 100°, gave me the following analytical results:

H_2O	12.98
SiO_2	38.99
Al_2O_3	33.62
CaO	.07
Na_2O	13.07
K_2O	1.12
	99.85

These figures confirm the previous analyses and show that the impurity which vitiated them must have been small in amount and similar in composition to the new zeolite. The latter, I think, may be considered as fairly well established, and its formula may be written $Al_3(SiO_4)_3 Na_2H,3H_2O$, which requires, water, 13.76; soda, 13.54; alumina, 33.41, and silica, 39.29. This composition and the manifest relations of the mineral to nephelite, the parent member of the group, naturally suggest for it the name *hydronephelite*, which seems to be both appropriate and descriptive. Chemically, as I have already observed, the species approximates to a soda thomsonite, but optically it appears to be quite different. This fact suggests the desirability of a careful microscopic re-examination of all the other massive zeolitic alterations of elæolite which, on analytical grounds, have been referred to the thomsonite series. Hydronephelite, indeed, is directly derived from sodalite, but the latter itself probably originated from elæolite; so that the new species may quite properly be considered along with the other zeolites which were previously mentioned. The fact that it contains more potassium than the sodalite is noteworthy and calls for an explanation which I am unfortunately not prepared to offer.

ALBITE AND LEPIDOMELANE.

The albite of Litchfield, which appears to be associated with other undetermined feldspars, is mostly in obscure masses. Occasionally a fragment is found with a translucent cleavage surface one or two centimeters broad. Such a specimen was partially analyzed, giving H_2O 0.52, SiO_2 66.39, Al_2O_3 19.69, K_2O 0.99, Na_2O 10.17. These figures serve only for complete identification of the species.

The lepidomelane exists abundantly in the elæolite rock, but mostly in small black scales. Sometimes tolerably large plates of it are found, black and brilliant, decidedly brittle, and apparently affected by altera-

tion. An analysis gave the following results. The iron determinations were made by Mr. Riggs:

H_2O	4.62
F	None
TiO_2	None
SiO_2	32.09
Al_2O_3	18.52
Fe_2O_3	19.49
FeO	14.10
MnO	1.42
MgO	1.01
K_2O	8.12
Na_2O	1.55
	100.92

This analysis is noteworthy on account of the extremely low percentage of silica, which is approached, so far as I can ascertain, only in an analysis by Rammelsberg of a black mica from Brevig. The ratio between silicon and oxygen is nearly 1 to 5, which agrees with no known formula. My results make it extremely probable that the mica is a mixture and that it has undergone an alteration tending toward the ultimate development of some chloritic species. Still it deserves, as also do the feldspars of the locality, a more thorough examination.

DISCUSSION OF FORMULÆ.

In attempting to discuss the formulæ of cancrinite, sodalite, and hydronephelite, certain points should be carefully borne in mind. First, the three species must be considered, not independently, but relatively to one another, for all the evidence indicates for them a common origin. That origin is from the first member of the group, elæolite or nephelite, the empirical formula for which has been finally fixed by Rauff.[1] In partially rational form it may be written $Na_8Al_8(SiO_4)_7(SiO_3)_2$, ignoring the small replacement of sodium by potassium, which has been shown by synthetic investigations to be non-essential. Not only does the mode of occurrence and association of the minerals point to community of origin, but the same conclusion is emphasized by the experiments of Lemberg[2] upon the artificial alteration of silicates. When elæolite from Fredriksvärn was digested one hundred and eighty hours with a solution of sodium carbonate, a partial transformation into a *soda* cancrinite was effected, while a digestion of six months with a caustic soda solution containing sodium chloride gave a product identical in composition with sodalite. Many such experiments were tried by Lemberg, yielding a large class of similar results. His method of procedure probably did not give absolutely pure or definite compounds, and yet his researches

[1] Zeitschr. Kryst. und Min., II, p. 445.

[2] Zeitschr. deutsch. geol. Gesell., XXXV, p. 557, 1883.

furnish evidence of great value in discussing the chemical structure of many minerals.

The taking up of sodium chloride by elæolite, both in the dry and in the wet way, has also been observed by Koch.[1] The easy alterability of elæolite, therefore, may be regarded as a point thoroughly established and to be taken into account in all discussion of it and its congeners.

If we compare the published analyses of cancrinite from different localities we shall find that they vary in two ways. First, there are variations which are probably due to admixtures of elæolite, such as I have shown to occur at Litchfield; and, secondly, the ratio between the lime and the carbonic acid ranges between rather wide limits. In the cancrinite from Miask, the two are about equivalent, while the Litchfield mineral contains only half enough calcium to saturate the carbonic acid. The lime and soda, however, vary reciprocally, so that when one is high the other is low; and, furthermore, the experiment quoted from Lemberg goes to show that a cancrinite may exist containing no lime whatever. If this conclusion be correct, then the carbonic acid of the mineral must be represented as linked with aluminum, a supposition which finds some justification in the existence of the rare species dawsonite. The function of water in cancrinite remains doubtful; if it be regarded as water of crystallization, the formula of the residue becomes less easy to write intelligibly; but, if it forms a part of the atomic structure, it is almost necessary to represent the carbonic acid as orthocarbonic in the group CO_4. This mode of consideration, as will appear later, leads to a simple general formula for cancrinite, covering all variations in composition except such as are due to impurity and correlating the mineral with the allied species sodalite and nosean. For the Litchfield mineral the following special formula may be written, giving the theoretical composition in the column below: $Al_8(SiO_4)_9(CO_4)_2CaNa_8H_6$.

	Found.	Calculated.
SiO_2	35.83 to 37.22	35.9
Al_2O_3	28.32 to 30.12	30.6
Na_2O	19.33 to 19.56	18.6
CaO	4.27 to 5.12	4.2
CO_2	6.22 to 6.96	6.6
H_2O	2.98 to 3.86	4.1
		100.0

In this case the water as found is slightly lower and the soda slightly higher than the calculated values, which is probably ascribable to the mutual replaceability of sodium and hydrogen.

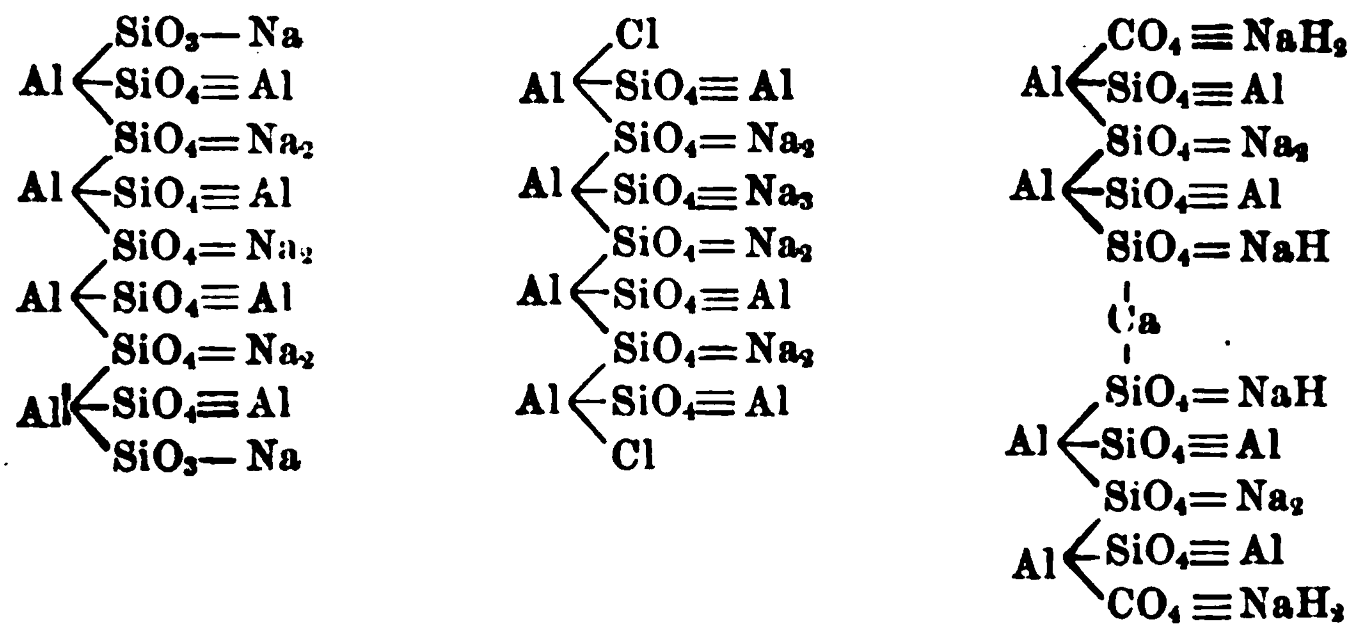
[1] Neues Jahrb., Beil. Bd. I, p. 143, 1881.

The formula commonly accepted for sodalite, and the one which is certainly the simplest, is that deduced by Bamberger[1] from his analysis of the mineral from Tiahuanuco. Written empirically, this formula is $Na_5Al_4(SiO_4)_4Cl$, which requires considerably less chlorine than has ordinarily been found in the species. In Bamberger's analysis, as finally corrected, he obtained 5.54 per cent. as against nearly 7 per cent. in Whitney's determinations. The difference he ascribes to silica in the chloride of silver, as weighed by other analysts; and yet in my own estimation every care was taken to eliminate such impurity, and my results confirm the older figures. Still, both figures have theoretical interest, as will be seen further on; and I am inclined to believe that the Bolivian mineral was more nearly typical than that from Litchfield. To the latter we may assign the empirical formula $Na_9Al_7(SiO_4)_7Cl_2$, which is directly derivable from the formula for nephelite and which agrees quite sharply with the analyses.

We now have three empirical formulæ ready for comparison side by side, as follows:

Nephelite..	$Al_8(SiO_4)_7(SiO_3)_2Na_8$
Cancrinite (Litchfield)........................	$Al_8(SiO_4)_8(CO_4)_2CaNa_8H_6$
Sodalite (Litchfield)...........................	$Al_7(SiO_4)_7Cl_2Na_9$

These may easily be put into structural form by an application of the principle suggested in a former paper,[2] that orthosilicates containing aluminum are to be represented as substitution derivatives of the normal salt $Al_4(SiO_4)_3$. The latter contains the fundamental nucleus $Al(SiO_4)_3$, which appears to be capable of a sort of polymerization, and which forms the basis of the subjoined symbols:



Nephelite. Sodalite. Cancrinite.

Now, although these formulæ fit the analyses and express a structural similiarity of type, two of them are capable of a further generalization. Remembering the reciprocal variations between soda and lime in different cancrinites and the fact that a soda cancrinite is quite pos-

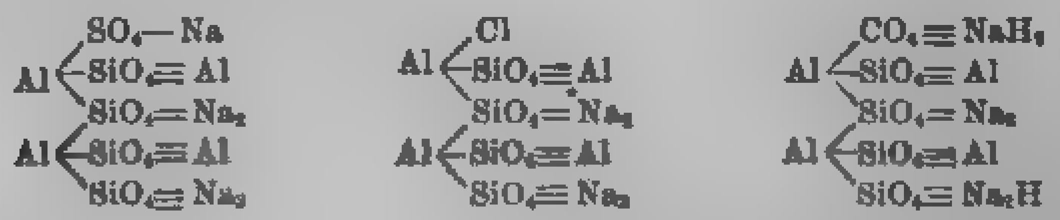
[1] Zeitschr. Kryst. und Min., V, p. 581.

[2] Topaz from Stoneham, Maine, Bull. U. S. Geol. Surv. No. 27.

sible, we may write the following general formula for that species: $Al_4(SiO_4)_4CO_4Na_5H_3$; which requires

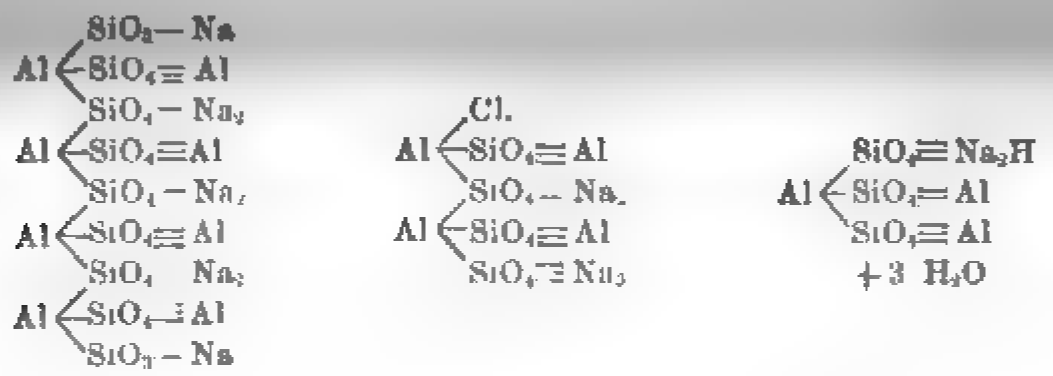
SiO_2	35.6
Al_2O_3	30.4
Na_2O (partly replaceable by CaO)	23.1
CO_2	6.6
H_2O	4.1

Comparing this with Bamberger's sodalite formula, and with the generally accepted formula for nosean, we have this remarkable series of structural expressions:



Nosean. Sodalite. Cancrinite.

The formula of hauynite of course reduces to the same type, and so also, probably, does that of microsommite. Hydronephelite has a still simpler formula, which, however, includes three molecules of water of crystallization. It may be advantageously compared in series with its parent minerals, in which case we have the following set of structures:



Nephelite. Sodalite. Hydronephelite.

These formulæ express with decided clearness the natural order of transition from one species to another. The alteration of a mineral necessarily involves the passage from a less stable to a more stable condition; and in this instance we observe precisely that state of affairs. From a quite complex and therefore easily disturbed molecule, through an intermediate, simpler compound, we pass to one which is simplest of all, and hence presumably the most stable. I do not deny that such formulæ are subject to criticism and that possibly the advance of knowledge may brush them to one side; and yet I feel justified in claiming that they have some real value in the co-ordination of observed facts, and that, through their singular suggestiveness, they assist in the prosecution of research.

TURQUOISE FROM NEW MEXICO.

By F. W. Clarke and J. S. Diller.

At Los Cerillos, New Mexico, about twenty-two miles southwest of Santa Fé, are mines of turquoise which have been worked for centuries. The locality has been repeatedly described[1] from archæological and geological points of view; but, so far as we are able to ascertain, the turquoise itself has never been fully analyzed, nor has it been subjected to complete microscopic study. Having at our disposal a very full suite of specimens, collected during the summer of 1885 by Maj. J. W. Powell, Director of the United States Geological Survey, we have thought it desirable to investigate the subject more thoroughly, and to present our results in such a form as to render them readily comparable with the published data concerning turquoise from other localities.

The turquoise occurs embedded in its matrix, sometimes in nodules, oftener in seams or veins. It varies in color very widely, ranging from a pure sky blue through many shades of bluish green and apple green to dark greens which show no blue whatever. The dark green nodules often shade off to nearly white at the center, sometimes resembling in structure, as Blake has observed, certain varieties of malachite. Many of the specimens are seamed or streaked by limonite, which has been derived from accompanying pyrite; and the latter mineral occasionally is found, bright and unaltered, inclosed completely in masses of clear blue turquoise.

For analysis, three samples of turquoise were selected, representing, as nearly as possible, the most definite types of the mineral. They may be summarily described as follows:

A. Bright blue, faintly translucent in thin splinters.

B. Pale blue, with a slightly greenish cast, opaque and earthy in luster, and of sp. gr. 2.805. Blake gives the density from 2.426 to 2.651 for the green variety.

C. Dark green, opaque.

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[1] W. P. Blake, Am. Jour. Sci. (II), XXV, p. 227, 1858. J. S. Newberry, Report of the Exploring Expedition from Santa Fé to the Colorado, &c., 1859 (Macomb's Expedition). B. Silliman, jr., Am. Jour. Sci. (III), XXII, p. 67, 1881.

	A.	B	C.
H_2O	19.80	19.60	18.49
Al_2O_3	39.53	36.88	37.88
Fe_2O_3	.....	2.40	4.07
P_2O_5	31.96	32.86	28.63
CuO	6.30	7.51	6.56
SiO_2	1.15	.16	4.20
CaO	.13	.38	Undet.
	98.87	99.79	99.83

Analysis A is not quite complete, for enough material could not be obtained without the destruction of too valuable specimens. The silica in it was due to traces of admixed rock, from w hich the material could not well be perfectly freed. C, however, was free from rock, and the silica in it must be accounted for otherwise. Silliman reports the turquoise as containing 3.81 of copper, which corresponds to 4.78 of CuO, but he gives no other quantitative data.

In attempting to discuss these results, it will be well to compare them with three other published analyses of turquoise from different localities. First, we have the figures given by Church[1] for the well known variety from Persia; secondly, the analysis by G. E. Moore[2] of turquois e pseudomorphous after apatite, from Taylor's Ranch, Fresno County, California; and, thirdly, Nikolaieff's[3] data concerning the mineral from Karalinsk, in the Kirghiz Steppes. These analyses may be tabulated as follows:

	Persia.	California.	Karalinsk.
H_2O	19.34	19.98	18.60
Al_2O_3	40.19	35.98	35.79
Fe_2O_3	....	2.99	3.52
FeO	2.21	....	....
MnO	.36	....	....
CuO	5.27	7.80	7.67
P_2O_5	32.86	33.21	34.42
	100.23	99.96	100.00
Sp. gr	2.75	2.798, 2.815	....

These analyses, leaving temporarily out of account that of the dark green variety, agree well with one another in their atomic ratios. Divid-

[1] Church, Chem. News, 10, p. 290; Dana's Syst. Min., p. 581.
[2] Zepharovich and Moore, Zeitsch. Kryst. und Min., 10, p. 240.
[3] In a paper by Kokscharoff, Neues Jahrb., 1886, I, Ref., 10.

ing the percentages by the proper molecular weights and treating the bases together, the following ratios appear:

	Total base.	P_2O_5.	H_2O.
New Mexico, A....	.468	.225	1.100
New Mexico, B	.479	.231	1.089
Persia............	.492	.231	1.075
California	.470	.234	1.110
Karalinsk	.470	.242	1.033

In each case the base stands to the acid in a ratio very slightly in excess of two to one, and that excess may fairly be accounted for upon the supposition that it represents a trifling admixture of limonite. The water is present in a proportion a little under that of five molecules to one of phosphoric acid, the variation here being due to differences in the percentages of copper. If we calculate the amount of phosphoric acid necessary to satisfy the alumina and then reckon the phosphate so obtained as requiring five molecules of water, we shall have left over a quantity of copper, acid, and water corresponding to a very simple formula, and the turquoise will appear as a variable mixture of the two following salts:

$$2\,Al_2O_3,\ P_2O_5,\ 5\,H_2O$$
$$2\,CuO,\ P_2O_5,\ 4\,H_2O$$

In the Californian turquoise the analytical results fit these formulæ quite sharply and give the ratio between the two compounds as approximately four to one. The first formula may be regarded as that of normal turquoise, and may be written in rational form, halved, as

$$Al_2HPO_4(OH)_4$$

The copper salt, to which the mineral owes its color, is to be considered merely as an impurity, a view which is emphasized by the analysis of the dark green turquoise C. In the latter case the same ratios apply, modified by the presence of silica, which is nearly sufficient to form with the copper a normal metasilicate, similar to if not identical with chrysocolla. This silicate, with whatever blue tinge of color it might have, affected by the yellow or brown of the iron present, probably gives the turquoise its green hue. It is exceedingly probable that the purity of tint in gem turquoise is due to the copper salt alone and that degradations of the color towards green are ascribable to admixture of salts of iron. It is noteworthy that of the three turquoises analyzed the bluest contains the lowest percentage of copper. This could hardly be the case were not the colors of the other samples modified by some impurities, and compounds of iron would naturally produce an effect in the observed direction.

Sections of the three varieties of turquoise were studied under the microscope and found to be of essentially the same character. Although

deeply colored in the hand specimens, the thin sections appeared almost clear and transparent. Between crossed nicols the deep blue and green forms were seen to be composed of minute grains or short, thick fibers, but in the paler varieties the fibrous structure was more pronounced. The optical properties of both grains and fibers are the same throughout. They are all weakly doubly refracting, but have a rather high refractive index. The finely granular portions have a pale bluish aggregate polarization, less intense than that of chlorite, but when the mineral is distinctly fibrous it polarizes like some forms of serpentine, with light colors of the first order. The fibers are generally somewhat bent and interwoven, but lie approximately in the same direction. Each fiber becomes dark when parallel to the principal section of either of the crossed nicols, indicating that they must crystallize according to the quadratic, hexagonal, or rhombic system, instead of in one of the inclined systems, as was the case with the fibers studied by Bücking[1] in the turquoise of Fresno County, California.

A section was prepared of a distinct vein of pale green turquoise, which showed that the fibrous structure is directly across the vein perpendicularly to its walls. Small fissures, running into or across the veins, have the fibers of turquoise arranged perpendicularly along their sides, just as serpentine arranges itself along fissures in olivine. Sometimes the fissures are minute and curved; but the resulting arrangement does not simulate the radial fibrous or spherulitic structure described by Bücking[2] as found in the turquoise of California, Nevada, and elsewhere.

The perpendicular arrangement of the turquoise fibers along fissures crossing the vein indicates that the mineral may have been derived from the alteration of another substance with which the vein was formerly filled. We would suppose, of course, that the original vein material was itself a phosphate; and the only one after which turquoise is known to be pseudomorphous is apatite, a species which not infrequently occurs in veins. The opinion that the turquoise has resulted from such an alteration is favored by the presence of other alteration products, to be noted in considering the composition of the country rock in which the turquoise is found. It is also suggested by Hermann's analysis of blue Oriental turquoise, in which the equivalent of 3.41 per cent. of calcium phosphate was actually determined.[3]

The rock in which the veins of turquoise occur is described by Blake as "a granular porphyry, yellowish, gray, or white in color, porous and earthy in texture. It decomposes rapidly by weathering and very much resembles a sandstone." In the collection made by Major Powell there

[1] See paper by Zepharovich and Moore, Zeitschr. Kryst. und Min., 10, p. 240, already cited.

[2] Zeitschr. Kryst. und Min., 2, p. 163.

[3] See Dana's Syst. Min., p. 581

are several good examples of the rock penetrated by the turquoise. It is a fine grained, reddish, feldspathic rock, mostly fresher than that described by Blake, and it has a microgranitic aspect. It contains numerous particles of biotite and pyrite, with stainings of oxide of iron. The hand specimens look as though they had been crushed, and the fissures thus formed so filled as to produce irregular veins and nodules. The veins are small and mostly composed of turquoise, in which are embedded a few scales of biotite, particles of pyrite, and considerable quartz and oxide of iron. Scales of biotite are found abundantly in the iron stained cavities, as well as in the solid portions of the rock. Some specimens of rock, containing much pale blue turquoise of earthy texture, have been completely kaolinized, and a partial analysis of the kaolin gave the following results:

H_2O	12.88
SiO_2	52.38
$Al_2O_3+Fe_2O_3$	33.49
P_2O_5	None
MgO	1.17
CaO	Trace
	99.92

Although the mineral itself was white, the alumina from it was distinctly reddish with the iron.

Under the microscope the rock is seen to be composed chiefly of feldspar, with a considerable amount of biotite, epidote, pyrite, and limonite, and some amorphous substance. It is somewhat microgranitic in structure, and the irregular interlocking grains of feldspar vary in size from .01 to .8^{mm} in diameter. Most of them are considerably kaolinized, so as to appear cloudy in ordinary light; but between crossed nicols the original outlines of the grains become more distinct. Their optical properties indicate that the feldspar is orthoclase, an opinion which is fully borne out by the subjoined analysis of the rock, which shows a remarkably large proportion of potash:

H_2O	3.28
SiO_2	56.68
Al_2O_3	16.62
Fe_2O_3	6.50
P_2O_5	.73
MgO	.79
CaO	.59
CuO	Trace, undet.
MnO	1.02
FeS_2	2.21
K_2O	11.18
Na_2O	1.03
	100.63

The porphyritic crystals are generally Carlsbad twins with irregular outlines. There are occasionally small grains of fresh, transparent plagioclase, which has evidently resulted from alteration.

The biotite of the rock occurs in noteworthy quantities, but is very unequally distributed. It is frequently aggregated in groups of scales and may be seen most abundantly in small cavities. It sometimes occurs intimately associated with the turquoise, but unlike the latter it is one of the primary minerals. The small quantity of quartz present is a secondary product, so intimately associated with turquoise as to suggest their genetic connection. Pyrite is scattered rather uniformly throughout the rock in small cubical crystals easily seen in the hand specimen. They are sometimes altered to limonite, but in other cases they have been completely replaced by pseudomorphs of epidote. The specimen of rock which was subjected to analysis probably contained an amount of pyrite rather greater than the average.

One of the most important constituents of the rock, because of its very close association with the turquoise, occurs in the form of bright yellow grains. They are not distinctly pleochroic, but have a high refractive index, with strong double refraction, and give brilliant aggregate polarization. The particles are usually very small and grouped together in irregular compound grains, so as to suggest nothing of crystallographic form. In several cases, however, elongated simple grains show inclined extinction, which indicates that the mineral must be either monoclinic or triclinic in crystallization. Judging not only from the properties enumerated, but also from the percentage of lime in the rock, this mineral is in all probability epidote. It is evidently connected genetically with the turquoise, for it is almost uniformly found upon the border of the latter and is most abundant in its neighborhood.

Concerning the origin of the turquoise bearing rock, it may be stated that Professors Newberry and Silliman, both of whom studied it in the field, regard it as eruptive and probably of Tertiary age. The occurrence of this veritable orthoclase rock in the West is of special interest from the fact disclosed by recent investigations that in many of the rocks previously described as trachytes the predominating feldspar is plagioclase.

The very small size of the veins and their limited distribution show that the turquoise is of local origin and emphasize the idea that it has resulted from the alteration of some other mineral. In addition to the evidence already cited to show that the turquoise has been derived from apatite, we have the fact that epidote, a lime bearing mineral, is present as a secondary product. The oxidation of pyrite may have had something to do with initiating the process of alteration and the alumina of the turquoise was probably derived from decomposing feldspar. The latter suggestion was made by Silliman, who also examined microscopic sections of the rock and reported apatite as present. No apatite, however, could be seen in the specimens examined by us. A search for it at the locality would certainly seem to be desirable.

THE GNEISS DUNYTE CONTACTS OF CORUNDUM HILL, NORTH CAROLINA, IN RELATION TO THE ORIGIN OF CORUNDUM.

BY THOMAS M. CHATARD.

The associations of corundum with the olivine or dunyte rocks of Western North Carolina and the adjacent portions of South Carolina and Georgia have been often described,[1] but, having had an opportunity during the summer of 1884 to visit a few of the typical localities and to collect specimens of the associated rocks, the results of my chemical examination of some of the latter are here given, as possibly affording some data for the solution of the problem of the origin of corundum.

The names given in this paper to the various rocks and minerals, unless analyses or authorities are given, must be considered as only approximately correct. By chlorite is meant all the varieties of green, foliated, hydrous, aluminous magnesian silicates met with in connection with dunyte, while the whole series of brown and yellow foliated minerals are called vermiculites. Under the heads of enstatite, talc, &c., are grouped a number of minerals of similar appearance, many of which may prove, on examination, to have compositions differing widely from that of the species under which they are placed.

In making the analyses, the silica, after being ignited over the blast lamp to constant weight, was treated with hydrofluoric acid and the residue deducted, while the alumina iron precipitate was, after ignition to constant weight, fused with sodic bisulphate, and silica, if present,

[1] C. U. Shepard, Am. Jour. Sci. (III), IV, pp. 109, 175, 1872,
J. L. Smith, Am. Jour. Sci. (III), VI, p. 180, 1873.
F. A. Genth, Am. Phil. Soc., Sept. 19, 1873, July 17. 1874.
J. P. Cooke, Proc. Am. Acad., Vol. IX, pp. 48, 49, 1874.
C. W. Jenks, Quar. Jour. Geol. Soc., XXX, pp. 303–306, 1874.
W. C. Kerr, Geol. N. C., I, p. 64, Supplement.
C. D. Smith, Geol. N. C., I, Appendix D, pp. 91–97; II, pp. 42, 43, 1881.
R. W. Raymond, Trans. Am. Inst. Min. Eng., VII, pp. 83–90, 1878.
A. A. Julien, Proc. Bos. Soc. Nat. Hist., XXII, pp. 141–149, 1883.
M. E. Wadsworth, Mem. Mus. Comp. Zoöl., Lithological Studies, pp. 118, 119, 1884.
T. S. Hunt, Trans. Roy. Soc. Can., Vol. II, Sec. III, §§ 37, 38, 1884.
T. M. Chatard, Mineral Resources U. S., 1883–'84, pp. 714–720, U. S. Geol. Survey, Washington, 1885.

separated. Double precipitation was always employed and the precipitates were carefully tested.

THE LOCALITIES.

The principal southern mining localities for corundum are at Corundum Hill, Macon County, North Carolina, and at Laurel Creek, Georgia, 26 miles southeast of the former. Both are owned and worked by the Hampden Emery Company, under the direction of Dr. H. S. Lucas, to whom I am indebted for every desired facility and for a very warm and intelligent interest in my work.

The two localities are alike in respect to the occurrence of the corundum. In both, the mineral is found in chlorite and vermiculite lying between hornblende gneiss and altered dunyte. At Laurel Creek the open cut in which the corundum is mined runs east 10°–20° north, following the course of the veins, the mine being situated on the north bank of Laurel Creek, at the base of a high hill. On the south bank and in the bed of the creek, hornblende gneiss is the country rock, succeeded as we go northwardly by enstatite, talc, and allied minerals. The corundum first met with occurs in what is locally known as the "sand vein," which is composed of chlorite and vermiculite carrying more or less corundum, usually in small crystals and fragments. The chlorite in the upper portion of this vein was much disintegrated, the mass falling readily to pieces, allowing of the easy removal of the corundum, but at the time of my visit it was very compact and tough and of little value. The sand vein is succeeded by a so-called "horse" of steatite, on the other side of which is the vein of "block corundum." This is a vein of vermiculite containing masses of corundum sparingly mixed with chlorite and vermiculite and frequently of great size, several having been obtained of at least 5,000 pounds in weight. One mass which I saw must have weighed at least a ton. The north wall of the block vein is a smooth wall of "indurated talc" and steatite, which gradually passes into altered but still hard dunyte. Indeed, the difference between this place and Corundum Hill is in no respect more marked than in the greater hardness and toughness of the corundum bearing rocks and in the apparent concentration of the corundum into large masses with but little evidence of crystallization. At the westerly end of the cut is a vein of decomposed white material shown by analysis to be an altered soda lime feldspar. In this I did not find any corundum, but I was told that it was occasionally found in this rock.

The Corundum Hill mine is situated on a ridge which runs in the northeast and southwest direction characteristic of this section, the dunyte outcrops being on the crest, and apparently surrounded on all sides except towards the east by hornblende gneiss. On the east side mica schist[1] takes the place of the gneiss, and it is on the eastern side

[1] Probably damourite schist; cf. Am. Acad., 1874, by F. A. Genth, "Damourite."

of the dunyte that the so-called "sand vein" is found. This is a vein-like mass of brown vermiculite in small scales containing an abundance of small crystals of corundum, which are usually brown in color and often broken into fragments. At the time of my visit the nearly perpendicular vein was about 6 feet wide and was worked by hydraulic washing through an open cut about 30 feet deep. The easterly wall of this vein is the mica schist very much decomposed, while on the western side we find enstatite, next vermiculite mixed with chlorite, then talc, which in turn gives place to nodules of more or less altered dunyte.

The specimens of corundum crystals for which this locality is so celebrated have all been found on the westerly side of the dunyte, and, so far as I have seen or could find out by inquiry from the owners and the miners, only on or near the lines of contact between the gneiss and the dunyte. The dunyte is sometimes, as stated by Julien in the paper cited, "interbedded with the hornblende gneiss in layers 1 to 6 meters in thickness. This was shown by a cross section of the beds on the north side of the dunyte deposit at the Jenks Mine (Corundum Hill), near Franklin, in Macon County. Although the dunyte is thus inclosed in or interbedded with the hornblende gneiss, the latter was never observed to be enveloped by the dunyte."

The origin of the dunyte, whether igneous or sedimentary, and, if the latter, whether mechanical or chemical, is a disputed question which has been ably discussed in the list of papers already given, and upon this point I am not able to give any further information of value. Leaving out the question of the origin of the dunyte, it appears very much like a dike or dike series, portions of which have been forced into the adjacent country rock without completely severing the connection with the main mass.

In its present condition it forms irregular spheroidal masses, sometimes several meters in diameter, most of which are much fractured and altered, the fracture seams being filled in with brown or yellow, clay-like, magnesian silicates, while the surface is also converted into a similar material which, when dry, has a strong tendency to peel off in semiconchoidal plates. In this form of alteration the mass of the nodule is still rather hard, but frequently the nodules are cased with talc, 10–20^{cm} in thickness and quite tough; when, however, this casing is pierced through, the interior is found to consist of a soft, yellow, ocherous material, into which a rod can be forced with comparative ease for a foot or more; towards the center of the nodule the material is often harder, being apparently less thoroughly decomposed.

The gneiss along the lines of contact is much decomposed, preserving its laminated structure but becoming a friable mass of reddish and brownish gray grains of quartz and scales of altered mica, with whitish nodules irregularly disseminated through it. Several contact sections from gneiss to dunyte were examined, and samples taken as the charac-

ter of the formation seemed to change. Of these the results of the chemical examination of one series is given, as it is typical of them all, the variations in the others being due, apparently, only to differences in the relative proportions of the same general classes of minerals.

DESCRIPTION OF THE SECTIONS.

These sections were all taken in an open cut which starts from a point near the corundum mill and runs into the hill in a southeast direction. In this cut the exposures were clearest, the banks in most of the other cuts being more or less covered, either by caving or by débris piled against them in the course of the mining operations.

In going up the cut the walls were found to consist in most part of the material which I have called altered gneiss, with occasional masses of dunyte very much altered and showing the characteristic chloritic minerals. The cut at the upper end widens out immediately after passing through a belt of gneiss which crosses it with a northeast, southwest strike and a dip which is apparently eastward, but is nearly perpendicular. This rock can be traced northeast for some distance, but is then covered by mining débris, though Dr. Lucas informed me that it continued without an apparent break through that portion of the ground. Beyond the rock piles it can be traced to the main body in the higher part of the hill.

On the east side of this gneiss and on the north side of the cut we have the following sequence:

Section A

A 1. Altered gneiss, becoming somewhat vermiculitic as it approaches A 2.
A 2. A narrow band of greenish chlorite.
A 3. A 6 inch seam of vermiculite.
A 4. Soft, yellow, magnesian clay.
A 5. A narrow seam of very impure chalcedony, stained red.
A 6. More yellow clay.
A 7. A rather hard casing, brownish yellow in color, inclosing
A 8. A large nodule of dunyte, much altered, with seams filled with soft clay and harder material of the same kind, while the comparatively hard brown yellow dunyte (A 8) has running through it small seams of
A 9. A mineral similar to enstatite.

Section B.

On the opposite side of the cut a section, B, starting from the same gneiss, shows—

B 1. Altered gneiss, like A 1.
B 2. About 2 feet (60^{cm}) of yellowish, micaceous, and quite rotten material.
B 3. About 30^{cm} of fine, scaly, brown vermiculite.
B 4. A band of foliated, compact, bright green chlorite stained bright red in places with ferric oxide or an iron clay.

B 5. Enstatite, gray in color and quite hard.
B 6. Yellow clay similar to A 6, and inclosing
B 7. Much altered but still rather hard dunyte, the casing on the other side being chlorite.

The corundum, when it occurs, is found in A 3 and B 3 and is much fractured.

Section C.

At about 10 meters northeast from A the Section C was made and gave the following series:

C 1. Altered gneiss, containing, distributed irregularly through it,
C 2. Harder nodules, very silicious; the gneiss gradually changing into
C 3. A scaly, brownish material, followed by
C 4. A soft, friable, yellowish white kaolin, intermixed with
C 5. A reddish brown, micaceous mineral, followed by
C 6. A seam of a small foliated, brownish yellow mineral which disintegrates easily, falling into small scales.
C 7. Vermiculite containing corundum. The specimen selected for examination was very typical and showed a mass of friable, yellowish brown vermiculite with a narrow seam of bright green chlorite dividing it into two nearly equal parts. The corundum is found on only one side of this chlorite seam, but is there in large proportion, some of the crystals being over 2^{cm} in length, the width of the corundum bearing streak being about 15^{cm}. The vermiculite containing the corundum was marked C 7 α; that on the other side of the chlorite, and which showed no corundum, C 7 β. This was followed by
C 8. A combination of vermiculite and actinolite.
C 9. Enstatite mixed with chlorite, forming a tough casing about 10^{cm} thick, inclosing a mass of altered dunyte with the yellow ochers and other characteristic decomposition products.

In giving the results of the examinations of these minerals it may be well to say that the rocks were always examined carefully with a strong lens and in most cases microscopically. The separations were made with Sonstadt's solution whenever practicable; but in the presence of the slimy, yellow, magnesian silicates this was often impossible, and hand picking was resorted to.

ANALYTICAL RESULTS.

C 1. Altered gneiss (?). A friable, sublaminated aggregate of scales of a micaceous mineral, in color from colorless to brownish and reddish yellow, with grains of quartz of similar shades of color and occasional small masses of a whitish, kaolin-like material (**C 2**). This rock has, as stated above, the same strike, dip, and structure as the adjacent unaltered gneiss and apparently passes into it.

C 2. Nodule in **C 1.** Structure finely granular, with larger grains of quartz disseminated through the mass, and a few small, yellowish scales on the fracture surfaces; rather friable; color brownish and yellowish white, with some small brown spots.

C 3. A friable aggregate of micaceous minerals, similar in structure and appearance to **C 1**, but the scales are smaller and more deeply col-

ored in shades of brown and yellow, the grains of quartz are fewer and smaller, and the nodules C 2 are absent.

	C 1.	C 2.	C 3.
Ignition	4.97	2.79	7.96
SiO_2	64.27	75.62	56.65
TiO_2	1.32	None	0.44
P_2O_5	0.05	None	Trace
Al_2O_3	16.75	12.52	21.60
Fe_2O_3	6.08	2.52	6.36
FeO	0.89	0.56	0.70
MnO	0.07	0.42	0.13
CaO	0.25	5.58	0.35
MgO	1.74	0.27	3.61
K_2O	3.09	None	1.98
Na_2O	0.89	None	0.59
	100.37	100.28	100.37

C 4. Soft, friable, fine granular, yellowish white, kaolin-like material, in lumps, with dark brown spots and streaks. Contains a very small proportion of fine grains of quartz.

C 5. The lumps of C 4 are scattered through a seam of a small foliated mineral aggregated to a loosely coherent mass which breaks up when handled. The scales have a pearly luster and are apparently colorless or of a greenish tint, but are stained reddish brown by interlaminated ferric oxide whichcannot be separated from them. When heated the mineral exfoliates slightly, assuming a silvery luster and a purplish red color. Before ignition, decomposable by hot, concentrated hydrochloric acid.

C 6. A compact mass of translucent scales; color, yellow with shades of brown; apparently homogeneous, but altered; disintegrates easily; contains a little chromite (0.15 per cent.).

	C 4.	C 5.	C 6.
Ignition	13.70	12.63	9.46
SiO_2	45.71	37.96	52.59
Al_2O_3	35.49	22.53	5.26
Cr_2O_3	....	....	0.52
Fe_2O_3	1.82	11.12	2.33
FeO	0.60	0.30	0.69
MnO	0.06	0.12	0.12
CaO	0.30	None	0.33
MgO	1.61	15.46	28.53
Alkalies	0.34	Undet.	0.16
	99.63	100.12	99.99

...s occurrence has been described above. The ...but little difference in physical characteristics, ...nd of a pale brown yellow color. The thinnest ...luster and are nearly transparent. C 7 α was ... and showed no corundum under a magnifying ...nce of it was shown not only in the course of the ... the process of grinding, as the vermiculite when ...free from grit. The corundum is probably inter... vermiculite, as is often seen in specimens which are ...ed;[1] moreover the corundum crystals, as separated ... are very much fractured and fall readily to pieces, ... plates. C 7 β appears to be free from corundum. ...iven with total amount of water and are also calcu... from corundum and dried at 110°, the latter calcu...hat the two vermiculites are practically identical.

...eam of chlorite separating these two was not examined ... did not differ apparently from the ordinary chlorites One chlorite (Analysis F, see page 56) has been exam... of its peculiar appearance, but in most cases it was not ...ary:

	C 7 α.		C 7 β.	
	Air dried.	At 110°.	Air dried.	At 110°.
Corundum	8.87	....	None	....
H_2O at 110°	10.33	....	11.42	....
H_2O at red heat	9.47	11.60	10.05	11.34
SiO_2	31.01	38.02	32.97	37.22
Al_2O_3	15.14	18.56	17.88	20.19
Fe_2O_3	5.63	6.90	4.76	5.37
FeO	0.55	0.68	0.57	0.64
MnO	0.12	0.15	Trace	....
CaO	0.35	0.44	None	....
MgO	19.08	23.38	22.36	25.24
Alkalies	0.22	0.27	None	....
	100.77	100.00	100.01	100.00

...mass of a yellowish brown, small foliated mineral, through the ...rt of which runs an irregular seam of a fine, granular, grass ...neral intermixed with a small quantity of black magnetic ...nd a large proportion of the vermiculite scales, which are, how...uch smaller than those of the outer portions. As there were con-

...s, quoted by Cooke, Proc. Am. Acad., 1874, loc. cit.; Genth, Am. Phil. Soc., ... 1873, section Chlorite.

siderable differences in the specific gravity of these minerals, they were separated by Thoulet's solution and marked C 8 α, C 8 β, and C 8 γ.

C 8 α. Small rounded grains showing some octahedral faces; opaque; luster, submetallic; color, brownish black; streak, blackish brown; magnetic. Analysis corresponds to chromite intermixed with some magnetite, but FeO was not determined for itself, the whole of the Fe_2O_3 being calculated as such.

C 8 β. Finely granular, compact, the larger pieces showing under the magnifying glass a crystalline structure and longitudinal striations; translucent to subtransparent; luster, vitreous; color, grass green; streak, greenish white; sp. gr., 3.062. Analysis corresponds to actinolite.

	C 8 α.	C 8 β.
H_2O at 110°	....	0.04
H_2O at red heat	....	0.52
SiO_2	3.20	55.23
TiO_2	0.36	None
P_2O_5	0.12	None
Cr_2O_3	45.94	0.19
Al_2O_3	2.51	3.04
Fe_2O_3	....	1.88
FeO	42.90	2.51
(Ni,Co)O	....	Trace
MnO	0.84	0.26
CaO	None	13.36
MgO	3.91	22.31
Alkalies	....	0.58
	99.78	99.92

C 8 γ. Foliated, compact; folia generally small, not over 2^{mm} across; cleavage, basal, eminent; color, yellowish brown, the thinnest scales being almost colorless, with a greenish tint; luster, submetallic, somewhat greasy, the material having a great resemblance to the so-called "bronze powder." Easily decomposed by concentrated hydrochloric acid, the silicic acid separating in pearly scales. When heated gives off much water and exfoliates with considerable force, particles being projected several centimeters from the mass, which doubles its bulk and becomes reddish brown with a somewhat silvery luster. Examined microscopically by Mr. J. S. Diller, who reports "that it is biaxial and negative, but the angle between the optic axes, as seen in a cleavage plate split off parallel to the base, is uniformly small. Upon rotating the section, although the cross is plainly distorted into two hyperbolæ, they do not completely separate from each other." Sp. gr., 2.613 in water at 25.5°.

In the following water determinations the figures in brackets represent determinations by difference, the others being direct determinations.

	Per cent.	Per cent.	Per cent.	Per cent.	Average.
H_2O at 110°	3.87	3.81	3.72	3.72	3.78
H_2O at 130°	0.12				
H_2O at red heat (blast lamp)	(6.83)	7.04	(6.95)	(7.00)	(6.98)
Total H_2O as determined	10.82	(10.85)	10.67	10.72	10.76

Analyses Nos. 1 and 2 are the results obtained on the air dried mineral; No. 3, average of 1 and 2, and No. 4 the average calculated as dried at 110°.

	1.	2.	3.	4.
H_2O at 110°	3.78	(3.78)	3.78	....
H_2O at 130° and red heat	6.98	(6.98)	6.98	7.22
SiO_2	39.89	39.74	39.81	41.17
Al_2O_3	12.88		12.99	13.43
Cr_2O_3	0.54		0.54	0.56
Fe_2O_3	5.29 = 18.82	19.04	5.29	5.47
FeO	0.11		0.11	0.11
MnO	0.05	0.05	0.05	0.05
CaO	0.14	0.13	0.14	0.14
MgO	24.88	24.78	24.83	25.68
K_2O	5.76	(5.76)	5.76	5.96
Na_2O	0.20	(0.20)	0.20	0.21
	100.50	100.46	100.48	100.00

No. 4 gives the atomic ratio:

$$\begin{array}{c}
\overset{..}{Si} : \overset{...}{\mathrm{R}} : \overset{.}{R} : \overset{.}{\mathrm{R}} : \overset{.}{H} \\
2.75 : \underbrace{1.03 : 1.29 : 0.14}_{} : 0.80 \\
2.75 : \quad 2.46 \quad : 0.80 \\
7 : \quad 6 \quad : 2
\end{array}$$

As this mineral appears to be a very definite vermiculite, I have, in order to distinguish it from the others, given it the name lucasite, in honor of Dr. H. S. Lucas, of Corundum Hill, North Carolina, and the

following table from Professor Cooke's paper[1] will show its relations to the other members of the group at 100°.

	$\ddot{\mathrm{Si}}$:	$\underbrace{\dddot{\mathrm{R}} : \dot{\mathrm{R}} : \ddot{\mathrm{R}}}$	: H
Hallite	2.42 :	2.41	: 1.47 or 8 : 8 : 5
"Lerni"........	2.54 :	2.50	: 1.30 or 2 : 2 : 1
Pelhamite......	2.75 :	2.46	: 1 26 or 9 · 8 : 4
Culsageeite	2.50 :	2.66	: 1.23 or 2 : 2 : 1
"Millbury"....	2.38 :	2.74	: 1.14 or 2 : 2 : 1
Jefferisite.......	2.56 :	2.53	: 1.17 or 9 : 9 : 4
Lucasite	2.75 :	2.46	: 0.80 or 7 : 6 : 2

C 9. Grayish white, asbestiform mass made up of fine fibers of a vitreous luster, aggregated to a somewhat woolly mass intermixed with a smaller proportion of bright green chlorite. The rock mass disintegrates easily, breaking down into a soft, woolly aggregate of fine needles, not folia. A hydrous enstatite. Sp. gr., 2.872.

H_2O	4.55
SiO_2	56.58
TiO_2	None
Cr_2O_3	0.24
Al_2O_3	1.74
Fe_2O_3	1.89
FeO	3.67
MnO	0.21
CaO	0.59
MgO	30.34
Alkalies	0.17
	99.98

The dunyte alteration following **C 9** was very much decomposed, being a friable, clay-like mass with needles of white, hydrous enstatite, like **C 9**, and small scales of another mineral which, however, could not be separated in a pure condition by means of Sonstadt's solution, as almost all the scales showed, when examined under the microscope, that they were interpenetrated by the needles. The examination of the decomposed dunyte of the **A** series will, however, show the character of these alteration products.

Of the following analyses, D is from the apparently least altered specimen of dunyte that I was able to find. It is granular, crystalline, the grains of olivine being subtranslucent, with a subvitreous luster and of an oil green color with grayish tints. The rock contains a little chromite.

Some of the specimens of dunyte, particularly the darker varieties, show an indistinct radiated structure, the radiations starting from points which are lighter in color than the rest of the specimen.

[1] Cooke, Proc. Am. Acad., p. 461, 1875.

E is my old analysis of dunyte from the same locality, given in Dr. Genth's first paper on corundum, already cited.

	D.	E.
Chromite	0.56	....
H_2O	2.74	1.72
SiO_2	40.11	41.58
Cr_2O_3	0.18	....
Al_2O_3	0.88	0.14
Fe_2O_3	1.20	....
FeO	6.09	7.49
NiO (tr. Co and Mn)	....	0.34
CaO	....	0.11
MgO	48.58	49.28
	100.34	100.66

A 7 is the casing of the dunyte nodule of the A series. It is brownish yellow, granular, and, when dry, easily pulverized; but, some portions appearing harder than the rest, the specimen was crushed without grinding, the coarse powder shaken violently and then sifted through a fine sieve. The softer part was called A 7 α, the harder A 7 β, and it will be seen that the two are practically alike, the harder part containing much more chromite and being not quite so much decomposed.

	A 7 α.	A 7 β.
Chromite	0.17	2.45
Ignition	2.14	2.01
SiO_2	40.04	40.18
Al_2O_3	3.17	1.35
Fe_2O_3	12.15	9.88
MgO	42.97	43.84
	100.64	99.71

A 8. Altered dunyte, granular, compact, traversed by small seams carrying A 9. Luster, dull; color, pale yellowish brown. From interior of nodule.

A 9. Fine fibrous or small foliated, the folia being so arranged transversely in the seams of A 8 as to present a fibrous appearance. Luster, pearly soft; color, colorless to white. Subtranslucent.

F. Chlorite; broad foliated, folia brittle, being probably somewhat altered. Color, dark bluish green; luster, submetallic. From Corundum Hill.

	A 8.	A 9.	F
H_2O	1.54	4.32	12.71
SiO_2	40.25	56.39	35.68
Al_2O_3	0.96	2.31	20.90
Fe_2O_3	2.71	0.16	6.55
FeO	5.97	1.96	3.69
CaO		0.04	0.14
MgO	47.76	34.57	19.90
K_2O			0.19
	99.19	99.75	99.95

In comparing these analyses with reference to the mode of occurrence of the corundum and to the question of its probable origin, it must be remembered that we start from an aluminous rock, gneiss, on one side of the seam, and, passing through the series, reach as a final term a magnesian rock, dunyte. In following the series we should expect to find a progressive increase in the amount of magnesia and a gradual decrease in the amount of alumina. It will be observed that such is the case with the magnesia, while, roughly speaking, it is also true of the alumina. The ease with which magnesia, in the processes of rock alteration, may be dissolved and redeposited explains the regularity of its increase, while the high degree of insolubility of silicate of alumina and the presence of varying quantities of kaolin in the specimens C 1 to C 6 account for the irregularities in the alumina percentages. The members of the series C 1 to C 6, though crystalline, are in nearly every case much decomposed and do not allow, generally, of proper separations. Enough has been done, however, to show that the entire series falls into three groups: aluminous silicates, alumino-magnesian silicates, and magnesian silicates. The list of constituents is practically the same for all, and it is only by considering the relative predominance of one or the other base that the distinction can be made. The middle term of the chemical series is also the middle term of the field series, and in it the corundum is found. All the gneiss dunyte contacts which I have seen or have information of give practically the same succession. Corundum is, however, only an accessory; frequently it is not found at all, and, when present, often in comparatively small quantities. It may therefore be considered as the result of a certain balance between the aluminous and the magnesian solutions, which have by their union produced the chlorites and the vermiculites.

The question of the origin of the dunyte, in so far as it has any reference to that of the corundum, can now be considered. Three modes of

origin are supposable, chemical, sedimentary, and igneous. If a chemical origin be assigned to the dunyte (and gneiss), we could have a sequence of events something like the following: An aluminous silicate solution depositing the constituents of gneiss gradually becomes impregnated with a solution of magnesia either as silicate, or, more probably, a mixture of silicate and carbonate. The researches of Way[1] and those of Deville, Friedel and Sarrasin, and de Schulten[2] have shown that aluminous silicates and alkaline silicates can be made to combine, forming feldspars and other alkaline-aluminous silicates, and Way showed that the alkali could be replaced by lime.

Although much more work is required in this direction, still we are warranted in assuming that, if we can obtain solutions of aluminous silicates and of magnesian silicates and allow them to react upon each other under proper conditions, we shall obtain hydrous-alumino-magnesian silicates, or if iron be present, as is the case with dunyte, silicates belonging to the chlorite and vermiculite groups.

Under this assumption, the rock forming solution would cease depositing the constituents of gneiss, even of the more hornblendic varieties, and, instead, furnish chlorites and allied minerals, until, gradually becoming more and more magnesian, enstatites, talcs, and finally chrysolites would be the products. To account for the formation of corundum during this process we must suppose the presence of carbonate of magnesia along with the silicate, which would permit of the replacement, by magnesia, of a part of the alumina, which would be precipitated either as the hydrate or, under conditions as yet unknown, as corundum.

If instead of a chemical origin for the gneiss and dunyte we consider them as results of either a sedimentary or an igneous action, we shall find the reactions involved in the alterations of these rocks to be of the same character. In either case we should have gneiss in contact with dunyte. As soon as alteration of the gneiss begins, the feldspar kaolinizes and the mica is attacked, yielding solutions of alkaline salts which have the property of dissolving alumina, and this action is increased by the presence of carbonic acid, while even solutions of iron silicates and magnesian silicates have the same effect.[3]

As Roth observes, accurate and sufficient data are lacking for the proper consideration of such questions, but enough is known to be able to say that the alteration of gneiss or granite furnishes a solution of silicate of alumina. On the other hand, the mode of alteration of olivine has been studied,[4] and we know that both magnesia and silica are removed, the former in excess and therefore probably as carbonate,

[1] Way quoted by Hunt, op. cit., § 97.

[2] Hunt, op. cit., §§ 98–99. Fouqué et Lévy, Synthèse des minéraux et des roches, pp. 32, 134, 161–164, Paris, 1882.

[3] Roth, Chem. Geol., Vol. I, pp. 112, 141–160, 305–334, Berlin, 1879.

[4] Roth, Chem. Geol., p. 113.

which, as such, is not an uncommon occurrence among these rocks. Iron would, of course, be dissolved in the same manner as magnesia.

Julien, in his paper already cited, says (page 147):

The corundum itself is in all cases, both in the veins and in the particles found in the gabbro, a secondary or alteration product. All the phenomena of alteration, both in the veins and rock masses, absolutely require and can be simply explained by the introduction of a solution of soda and alumina into the fissures and interstices during the period of alteration and metamorphism. The combination of soda with silicates of alumina and iron, perhaps previously formed, has produced all the minerals of the vein series; while the precipitation of the alumina naturally ensued from the separation of its alkaline solvent. The question then presents itself of the evidence of the introduction of such a solution. This is found in the strata of hornblende gneiss, which everywhere surround the dunyte beds and are abundantly traversed all along the dunyte belt by huge veins of endogenous granite. Into these there has certainly been an introduction, by subterraneous thermal solutions, of soda and alumina, as shown both by the development of a long series of crystallized mineral silicates containing those bases with other elements, and, elsewhere, even by the precipitation of corundum itself (in association with muscovite, margarite, and albite) in a certain class of small veins in the gneiss of limited occurrence but of great interest.

Professor Julien's extended field experience among these rocks gives great weight to his opinion that corundum is a product of rock alteration. It is, indeed, difficult to see how a different opinion can be arrived at, if these rocks are studied in the field. In my own case, my field notes, written before I had an opportunity to see his valuable paper, indicate the same conclusion. Whether the solutions of soda and alumina must be heated in order to effect the production of these minerals is a question to which, at present, no definite answer can be given; but it would seem that the ordinary subaërial decay of these rocks should furnish the necessary solutions. The observations of Becker and the experiments of Barus[1] show that there is considerable doubt as to any production of heat as a result of the kaolinization of feldspar, and if such is the case with feldspar it is not likely that the alteration of any of the other mineral species present in these rocks would be attended by any marked rise in temperature. We must therefore conclude that the gneiss can furnish an alkaline solution of alumina and the dunyte a solution of magnesia without the production of heat and perhaps without its aid. Unless heat be absolutely necessary, either for the production of these solutions or for the formation of the contact minerals, we have no need for the introduction from a deeper source of a heated solution of alumina and soda, as the solutions furnished by the rocks at the contact should be sufficient for the purpose, and, by their meeting at the contact of the formations, give rise to the reactions stated above, namely, the production of chlorites and vermiculites, and, if the necessary conditions of proportion are reached, of alumina or corundum. That these conditions are often lacking is shown by the comparative

[1] G. F. Becker, Geol. of Comstock Lode, Mon. U. S. Geol. Surv., Vol. III, Chaps. VII and IX.

rarity of the occurrences of corundum when the number of such chlorite bearing contacts is considered.

Among the miners chlorite or vermiculite is considered a "corundum sign," and they follow it as long as it holds out. The chlorite veins often extend for some distance into the dunyte, as should be expected when we consider the thoroughly fractured condition of the dunyte, with its consequent spheroidal alteration forms; but, in such cases, the connection with the contact can generally be traced. In the same manner the chlorite seams may extend into the gneiss.

It has already been said that the dunyte of Corundum Hill lies between hornblende gneiss and mica schist. The same can be said of the locality at Unionville, Chester County, Pennsylvania, and, to a certain extent, of that at Chester, Massachusetts.

Mr. W. W. Jefferis has kindly furnished me with much information about the former place, where the serpentine (probably resulting, as stated by Genth,[1] from the alteration of chrysolite rocks) lies between mica schist on the north and hornblende gneiss on the south. The great mass of corundum which was found at this place lay on the north side, in the serpentine, a short distance from the mica schist, and was accompanied by chlorite. "It was between well defined walls of serpentine" (Jefferis). At a point on the south side of the serpentine, at the contact with the hornblende gneiss, is "a digging 15 feet deep, which produced 500 pounds of extra fine, blue corundum, similar to the blue from Macon County, North Carolina. Culsageeite occurs here identical with the North Carolina specimens. Both the corundum and the culsageeite are so much like the Carolina mineral that it is difficult to tell them apart" (Jefferis).

The deposit at Chester, Mass., is a vein of emery situated nearly in the center of the Green Mountain chain.

It is included in the metamorphic series of rocks, here consisting of vast breadths of gneiss and mica slate, with considerable interpolations of talcose slate and serpentine. Strike, N. 20° E.–S. 20° W.; dip from vertical to 75°–80°, sometimes east, sometimes west. The immediate vicinity of the mine presents a succession of lengthened rocky swells, the longer axis of the elevations generally coinciding with the direction of the strata.

The emery vein traverses, in an unbroken line, the crests of two of these adjacent mountains, and is about 4 miles long and about 4 feet wide. It lies at the junction of the gneiss with the mica slate, just within the western edge of the gneiss, having throughout a layer of gneiss 4 to 10 feet in thickness for its eastern wall. Between this layer of gneiss and the mica slate is talcose slate about 20 feet thick at the south end and widening out at the northern end to nearly 200 feet.

[1] Genth, Am. Jour. Sci. (II), XXXIII, p. 202, 1862.

The gneiss is highly hornblendic; where hornblende is rare, epidote is found. Quartz is very deficient and no corundum is found in the gneiss. The talcose slate carries soapstone, chlorite, talcose dolomite, &c., and contains, here and there, corundum. Quartz is very rare. In the vein are found corundum, magnetite, margarite, ripidolite, biotite, andesite, tourmaline, and titaniferous iron.[1]

Whether or not this locality can be placed with those already described is a question to which, not having visited the mine, I cannot give an answer. There are many points of similarity, but the presence of the thin wall of gneiss on the eastern side of the vein brings a difficulty into the consideration of the problem. The presence of magnetite must also be explained; and, as the action of lime is here evident, it may be that this occurrence must be placed with that of the Cullakenee or Buck Creek Mine, Clay County, North Carolina, where lime has also played a part, as shown by the presence of margarite, zoisite, and oligoclase, the last carrying corundum.

The action of lime brings us to the occurrences of corundum in crystallized limestone, of which the emery deposits of Asia Minor and the Greek Islands, studied by J. L. Smith,[2] are the most important. In his memoir he says:

> In every instance I have found the emery associated with the old limestones overlying mica slate, gneiss, &c. It is embedded either in the earth that covers the limestone or in the rock itself, and exists in masses from the size of a pea to that of several tons' weight, generally angular, sometimes rounded, and, when in the latter form, they do not appear to have become so by attrition. * * * The emery has been formed and consolidated in the limestone in which it is found and has not been detached from older rocks, as granite, gneiss, &c., and lodged in the limestone at the time of its formation. My reasons for so thinking are the following:
>
> (1) In no instance could the closest investigation of the older rocks of these localities that are below the limestone furnish the slightest indication of the existence of emery there; and, moreover, the masses of emery in the limestone never had fragments of another rock attached to them. A few thin layers of mica slate were found in the limestone, but they were not in contact with the emery, nor contained any traces of corundum.
>
> (2) The limestone immediately in contact with the emery differs almost invariably in color and composition from the mass of the rock; and at Kulat, where the marble forming the rock is remarkably pure, the part in contact with the emery is of a dark yellow color resembling spathic iron, and contains a large portion of alumina and oxide of iron. The thickness of this interposing coat between the emery and the marble is variable; but, what is certain, it passes gradually into white marble, so that their crystalline structures run into each other, showing that they are one and the same rock. * * * What we see is just what should be expected in ferruginous and aluminous minerals forming and separating themselves from a limestone not yet consolidated.

Other reasons are given to prove this point, and he gives a most instructive example of a nodule of emery surrounded by two concentric layers, the inner of chloritoid, a hydrous silicate of alumina and iron,

[1] J. L. Smith, Am. Jour. Sci. (II), XLII, pp. 83-93, 1866.

[2] Am. Jour. Sci. (II), X, pp. 354-370, 1850; XI, pp. 53-66, 1851.

the outer of margarite, a hydrous silicate of alumina and lime. Finally he says:

At some future time * * * it will doubtless be found that emery forms the geognostic mark of extensive calcareous formations in that part of the world, just as the flints do in the chalk of Europe.

CONCLUSION.

From the foregoing examples it would seem that we have three types of corundum occurrences:

(1) In chlorites and allied minerals, the result of contact alterations between aluminous-alkaline silicate rocks and magnesian silicate rocks.

(2) In soda-lime feldspars, mainly depending upon the same reactions as No. 1, but complicated by the action of lime.

(3) In crystallized limestone, represented by the emery occurrences and that at Vernon, Sussex County, N. J., described by W. P. Blake.[1] As to the character of the reactions producing this last class of occurrences, I am not at present able to say anything, and it will require a careful study of the relative influence of magnesia and lime, in this connection, before any hypothesis can be stated.[2]

In considering the second type the facts that the feldspar is always a soda-lime feldspar, that it is found in connection with occurrences of the first type, and that margarite and other lime minerals are found in association point to a modification of type No. 1 through the action of lime. If the "hornblende gneiss" of the Buck Creek or Cullakenee Mine proves to be diorite, as has been stated, then we may be able to form a simpler idea of the course of the reactions.

The mode of origin of the dunyte is readily seen to be foreign to that of the corundum, since the chemical reactions involved in the production of the latter are practically the same under each theory. If a chemical origin be assigned to the dunyte, then the corundum and chlorite would be formed posterior to the gneiss and anterior to the dunyte, or even vice versa. If either the mechanical sedimentary or the igneous theory be assumed, then the corundum is posterior to both gneiss and dunyte and contemporary with the chlorite (and vermiculite), the two being equally alteration products. On the whole, it would seem that an igneous origin for the dunyte offers the simplest explanations.

That the chlorite and the corundum are contemporaneous is made evident by the intimate manner in which the two have crystallized together. In general the plates of chlorite would seem to have attained considerable size before the corundum began to deposit and fill up the interstices, so that we have compact masses ranging all the way from almost pure corundum to almost pure chlorite. The "block corundum" of Laurel Creek is an example of the first class, while the "sand vein

[1] Am. Jour. Sci. (II), XIII, p. 116, 1852; C. U. Shepard, Am. Jour. Sci. (III), IV, p. 179.

[2] J. L. Smith, Am. Jour. Sci. (III), VI, p. 182.

chlorite" of the same place shows the latter form. While perfectly formed crystals of pure corundum are not uncommon, we frequently find crystals with regular faces, but apparently formed in a solution having large numbers of small plates of chlorite or vermiculite floating in it, so that the corundum crystals carry many of the folia inclosed in them. If such a crystal, carrying vermiculite, is boiled in acid, the vermiculite is decomposed and more or less of the crystal disintegrates into corundum sand. Such crystals are found at Corundum Hill and specimens exist in the collection of the National Museum.

Whether or not the vermiculites are to be considered as resulting from the alteration of chlorites is a disputed point. Specimens are frequently found which show an apparent change from chlorite into vermiculite, the dark green folia of the one passing into the yellow brown of the other,[1] but in most cases it is difficult to resist the conclusion that the chlorite now found with the vermiculite is not the residue of a process which has converted the rest into vermiculite. Such specimens from Corundum Hill show the chlorite apparently perfectly fresh and the form of the mineral entirely distinct from that of the associated vermiculite, being usually much more broadly foliated. Moreover, we find seams containing but little chlorite, the corundum being surrounded by vermiculite, while, but a short distance away and under apparently like conditions of exposure and weathering, veins are found filled with chlorite almost free from vermiculite. In this connection the observations of Cooke[2] are very interesting, and from what we know at present the derivation of one from the other is very doubtful. As to the relation of the chlorites (including vermiculites) to corundum, it is possible that this mineral may, in the process of alteration, occasionally furnish them; still, so far as field experience teaches, these minerals are the original gangue of the corundum and are not derived from it. The valuable researches of Dr. Genth have shown that this mineral does alter, and, in so doing, produces many different mineral species; but whether any given mineral occurring with corundum is a result of the alteration of the latter must be determined for each case by the examination not only of the specimen but of its field surroundings also. Even when we have before us an apparently decided pseudomorph of some mineral after corundum it may prove to be only a case of envelopment, and this is particularly likely to be the case where the mineral in question is found free from corundum in the same vein or even the same locality. Both damourite and margarite are found enveloping corundum, the outlines of the mass closely imitating the form of the inclosed crystal, so as to be easily mistaken for a true pseudomorph, and yet both of these minerals occur with corundum in such a manner that it is hardly possible to conceive that they are derived from it. The same may be

[1] Genth, op. cit., 1873, section "Jefferisite."

[2] Cooke, Proc. Am. Acad., Vol. IX, pp. 49-50, 1874.

said of the lime-soda feldspars, which, in general, present all the appearance of a gangue and not of an alteration product.

In concluding this paper it may be said that the information on this subject which has been gathered by different observers, while in the aggregate of considerable extent, is so far neither sufficient nor of a character to enable any one to speak with any great degree of confidence as to the mode of origin of this interesting mineral. Much more work, both in the field and in the laboratory is necessary; and, as a thorough investigation in this direction cannot fail to elucidate many points of great value to chemical geology, it is to be hoped that such work will be done. The value of corundum from the practical standpoint, the ease with which it can be recognized when occurring with other minerals, the great scientific importance of alumina, not only in its pure and crystallized condition, but also as a principal constituent of the earth crust, and therefore playing a part in almost all geognostic reactions, its varied and sometimes inexplicable chemical behavior, all tend to promise a rich return to the well equipped investigator.

A METHOD FOR THE SEPARATION AND ESTIMATION OF BORIC ACID, WITH AN ACCOUNT OF A CONVENIENT FORM OF APPARATUS FOR QUANTITATIVE DISTILLATIONS.

By F. A. Gooch.

In all successful methods for the estimation of boric acid, its comparative isolation is a necessary preliminary. Fortunately, the removal of nearly everything which interferes seriously with the proper execution of methods is not particularly arduous, but, of ordinarily occurring substances, two, silica and alumina—both very commonly associated with boric acid—are especially annoying in this regard. In the separation of alumina the trouble lies in the tendency of the precipitated hydrate to carry and retain boric acid,[1] so that the two cannot be parted by means of ammonia or ammonia salts; with silica, the difficulty is in removing it completely. The volatility of boric acid stands, of course, absolutely in the way of treating with acid and evaporating to dryness, and every chemist knows the vainness of attempting to precipitate silica by means of ammonia, ammonia salts, or zinc oxide in ammonia. In Stromeyer's method[2] the presence of silica is peculiarly harmful, since in passing to the condition of potassium fluosilicate this substance nearly quadruples its weight, and to free the potassium fluoborate from contaminating fluosilicate requires, according to Fresenius,[3] at least six treatments by solution in boiling water, the addition of ammonia, and evaporation to dryness. Wöhler[4] recommends evaporating the hydrochloric acid solution to dryness in a flask fitted to a condenser, collecting the distillate, reuniting the latter with the residue, and filtering from silica; and the operation is successful so far as the complete removal of silica is concerned, but the alumina, if present, is still in condition to give annoyance, and the other bases are yet to be separated.

Advantage has long been taken of the volatility of free boric acid with hydrofluoric acid or with alcohol to secure its removal from fixed substances, but so far as I know no attempt has been made heretofore to secure its complete volatilization and estimation in the distillate. The experiments which I proceed to describe are the result of an effort to accomplish this end.

[1] Wöhler, Ann. Chem. und Pharm., CXLI, p. 268.

[2] Ann. Chem. und Pharm., C, p. 82.

[3] Quant. Chem. Anal., p. 424.

[4] Handbook of Mineral Analysis, under Datholite.

Aside from the difficulties in manipulation and in the construction of apparatus which the use of hydrofluoric acid would involve, this reagent is otherwise plainly inapplicable to the purpose in view, and of other agents with which boric acid is known to volatilize freely methyl alcohol seems to present the most desirable qualities. Methyl alcohol, ethyl alcohol, and water are effective in the order in which they are named. Thus to volatilize 1 grm. of boric acid—the equivalent, speaking roughly, of about 0.5 grm. of boric anhydride—two treatments with 10 cm.^{3} of methyl alcohol and evaporation to dryness in each case were adequate; for the volatilization of 0.2 grm. of boric acid were required two treatments of 10 cm.^{3} each of ethyl alcohol, succeeding an evaporation with 50 cm.^{3} of the same alcohol; and the residue of five evaporations of water over 0.4 grm. of boric acid, taking in each case 50 cm.^{3} of water, followed by ignition, weighed 0.08 grm., or one-fifth of the original weight. In the presence of water, methyl alcohol is not equally effective; amyl alcohol and sulphuric acid restrain its action similarly, doubtless by dilution simply, and hydrochloric acid seems to possess no advantage over water alone in developing the volatility of boric acid. As an example an experiment may serve in which a solution of 0.4 grm. of boric acid in 50 cm.^{3} of water, after being heated three times successively with 25 cm.^{3} of methyl alcohol until the boiling point rose in every case nearly to that of water, and then evaporated to dryness, left a large residue which disappeared with a single charge of 25 cm.^{3} of methyl alcohol applied by itself.

From the residue of the evaporation of borax with hydrochloric, nitric, or acetic acid, methyl alcohol, as would naturally be predicted, volatilizes the boric acid freely, though the presence of foreign material acts to a certain degree protectively and tends to diminish the rapidity with which the alcohol would otherwise effect extraction and volatilization. In case, however, that acetic acid is used to break up the borate, the tendency of sodic acetate to lose acid and become alkaline simply by exposure to evaporation in its aqueous solution makes it necessary to insure the acidity of the residue of evaporation by adding a drop or two of acetic acid before repeating the treatment with methyl alcohol.

On the whole, methyl alcohol shows itself to be an excellent agent by which to secure the volatilization of boric acid.

To retain free boric acid, magnesium oxide naturally suggests itself. According to Marignac[1] it is effective, and, if in the course of analysis it may have been partly converted to the chloride, it is easily regenerated by the action of heat and moisture. Marignac, it will be remembered, makes use of magnesia mixture—the chlorides of ammonium and magnesium with free ammonia—to fix the boric acid, evaporating the solution to dryness, igniting, extracting with boiling water, filtering, and weighing the residue, while the filtrate is again treated as before to re-

[1] Zeitschr. anal. Chem., I, p. 406.

cover traces of the borate which has yielded to the solvent action of the water. During the drying and ignition the magnesium chloride yields hydrochloric acid, and it would seem scarcely possible that the magnesium borate should fail to show some loss of boric acid when both hydrochloric acid and moisture exert their action. Further, the presence of ammonia during evaporation does not prevent the volatilization of boric acid,[1] and Marignac regards the addition of it from time to time as of doubtful use. So it appears natural to look for some loss under such conditions, and Marignac fully recognizes the fact that the apparent accuracy of his method is due to the balancing of errors, the inclusion of foreign matter by the magnesium borate and the deficiency of the magnesia when precipitated as ammonio-magnesium phosphate together compensating for the loss of boric acid by volatilization. To bring the matter to the test, the following experiments were made. In them and in all succeeding experiments the boric acid was weighed in solution, the standard of this having been fixed by dissolving in a known weight of water a known weight of fused boric anhydride prepared in a state of purity by frequent recrystallization. The magnesium oxide employed was made from the pure chloride by precipitating by ammonium carbonate and igniting, and was free from lime and alkalies and so far as could be determined was otherwise pure. The whole operation of each experiment was conducted in one vessel, so as to avoid transfers. In all cases a weighed platinum crucible of 100 cm.[3] capacity received a weighed portion of magnesia, and after ignition and subsequent weighing the weighed solution of boric acid was introduced. In experiments (1) to (4) the magnesia was thoroughly stirred in the solution of boric acid, the evaporation carried at once to dryness, and the crucible and residue ignited and weighed; in experiments (5) to (8), the magnesia was dissolved, after the addition of the boric acid, in hydrochloric acid sufficient in amount to prevent the precipitation of magnesium hydrate on the subsequent addition of ammonia, ammonia introduced in considerable excess in (7) and (8), in distinct excess in (5) and (6), the whole evaporated and ignited, the residue moistened and again ignited, and this last treatment repeated until the residue ceased to yield vapor of hydrochloric acid when heated.

	B_2O_3 taken.	MgO taken.	$MgO+B_2O_3$ found.	B_2O_3 found.	Error.
	grm.	grm.	grm.	grm.	grm.
(1)	0.1734	0.5005	0.6607	0.1602	0.0132 –
(2)	0.1804	0.4973	0.6660	0.1687	0.0117 –
(3)	0.1793	0.4949	0.6640	0.1691	0.0102 –
(4)	0.1794	0.4941	0.6627	0.1686	0.0108 –
(5)	0.1807	0.4984	0.6542	0.1558	0.0249 –
(6)	0.1789	0.4974	0.6687	0.1560	0.0229 –
(7)	0.1806	0.4944	0.6684	0.1740	0.0066 –
(8)	0.1789	0.4959	0.6672	0.1713	0.0076 –

[1] Rose, Pogg. Ann., LXXX, p. 262.

From these results it appears plain that under the conditions of the experiments neither magnesia alone nor the magnesia mixture is efficient in fixing boric acid; but in experiments (7) and (8), in which ammonia was employed in large excess, the loss of boric acid is least; so that it would seem to be the case that though ammonia is not a perfect preventive of volatilization it does exert a restraining action on the boric acid. That the magnesia mixture should be incapable of retaining entirely the boric acid present is, as has been pointed out, not surprising; but that the loss should be so great is rather startling, and more than suggests that the errors of Marignac's process are seriously excessive. The failure of magnesium oxide to hold back boric acid under the conditions of the experiment must be due to a cause other than that which determines the loss during the evaporation and ignition of the magnesia mixture, and for this it is natural to turn to the insolubility of the oxide, a quality likely to oppose some difficulty in the way of establishing complete contact between the boric acid and the magnesia during a short exposure. Direct tests of this point showed distinctly that mixtures of boric acid in water and magnesia, when submitted at once to distillation, yielded boric acid to the distillate; but that, if the mixtures were permitted to stand some hours before distilling, the oxide passed to the semigelatinous condition of the hydrate and retained the boric acid so firmly that turmeric failed to show the presence of the latter in the distillate. It is plain, therefore, that with sufficient preliminary exposure magnesia might be relied upon to retain boric acid; but inasmuch as long and perhaps somewhat indefinite periods of waiting are objectionable in any analytical process, it was thought best to try the effect of substituting lime for magnesia. Experiments (9) to (12), conducted like the previous ones, excepting only the use of carefully prepared and ignited calcium oxide instead of magnesium oxide, were made with this end in view.

	B_2O_3 taken.	CaO taken.	$CaO+B_2O_3$ found.	B_2O_3 found.	Error.
	grm.	grm.	grm.	grm.	grm.
(9)	0.1810	0.9737	1.1560	0.1823	0.0013+
(10)	0.1819	0.9750	1.1583	0.1833	0.0014+
(11)	0.1808	0.9922	1.1810	0.1818	0.0010+
(12)	0.1833	0.9715	1.1560	0.1845	0.0012+

These figures indicate sufficiently that there is no loss of boric acid by volatilization when its aqueous solution is evaporated in contact with calcium hydrate; but, inasmuch as the comparative solubility of the latter is the quality which makes it effective where magnesia is not, it seemed desirable to test the action of calcium hydrate in alcoholic solutions, in which it is very insoluble. The experiment showed that when the solution of boric acid in methyl or ethyl alcohol is put upon lime and distilled at once loss is apt to take place, and sometimes to a very considerable amount, but that a short period of digestion, with

occasional stirring—from five to fifteen minutes—is sufficient to obviate danger of volatilization of boric acid.

It appears, therefore, that, free boric acid being easily volatilized by means of methyl alcohol and fixed completely by calcic hydrate, the separation of the acid from almost everything with which it occurs ordinarily and its estimation subsequently depend only upon the practicability of distilling it from its compounds in such company that it may be retained by lime and its amount determined by the increase in the weight of the latter. Unlike magnesium chloride, calcium chloride does not yield its chlorine readily under the action of heat and moisture naturally retained; so that hydrochloric acid must not be present with boric acid which is to be estimated in the manner described. Calcium nitrate and calcium acetate both yield the oxide without difficulty upon ignition, and nitric and acetic acids are suitable agents, therefore, for the liberation of boric acid previous to distillation.

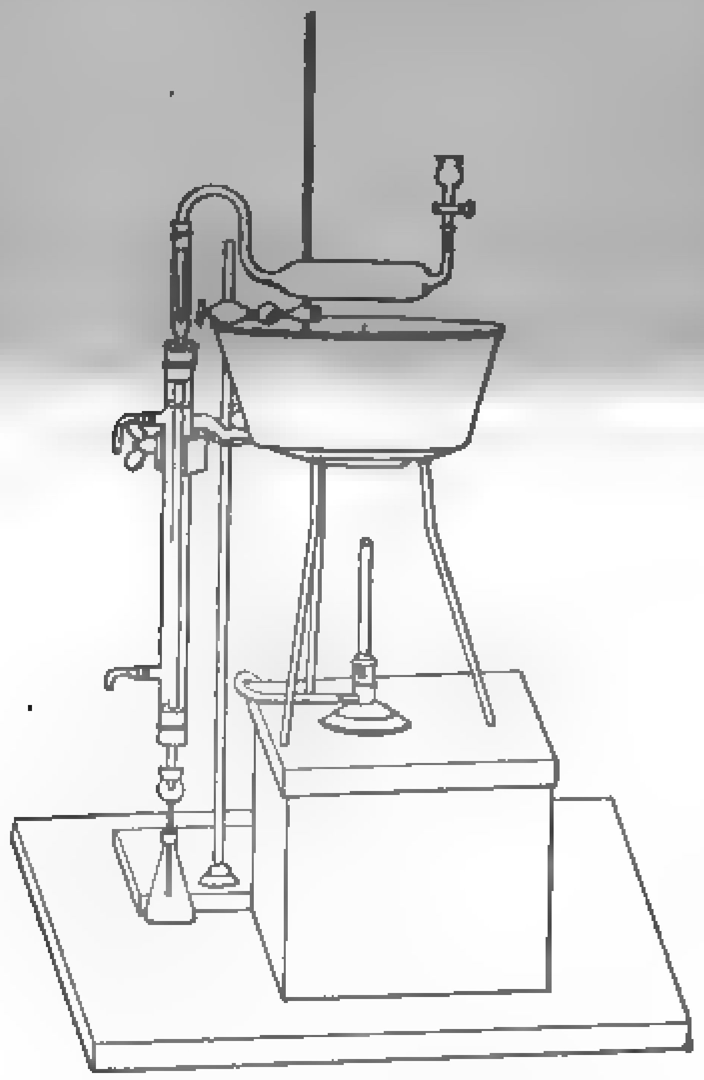

FIG. 3. Apparatus for determination of boric acid.

The actual distillation presented at first some difficulty, for the repeated, thorough, and rapid evaporation of a liquid charged with soluble or insoluble solid matter is apt to involve some mechanical transfer to the distillate of material which should remain in the residue; but the device of the following description solves the problem successfully.

The apparatus which is shown in the accompanying cut consists essentially of a retort, a condenser, and a bath for heating. For the last I have used a paraffine bath, as being, on the whole, the most convenient. The condenser is set vertically, to facilitate changing the level of the retort within the bath and to secure at the same time continual and thorough washing of the tube by its own condensations. The retort, somewhat like the well known drying tube of Liebig in general shape, is easily made of a pipette by bending the tube at one end to a right angle, at the other to a goose neck, as shown. To the former end is fitted, by a rubber stopper or section of tubing, a glass funnel tube provided with a stop cock; the end of the goose neck passes tightly through a rubber stopper in the upper end of the condensing tube. This is essentially the apparatus, but it is convenient to attach, to receive the distillate, a small Erlenmeyer flask, which moves with the condenser and is joined to it, in the manner indicated in the figure, by means of a thistle tube and a rubber stopper grooved to permit the free passage of air. In carrying out a distillation, the liquid to be distilled is introduced into the retort either by the funnel tube or previous to its insertion, the glass cock is closed, the water started through the condenser, and the retort lowered into the hot paraffine, care being taken to begin the operation with the retort not more than half full and so inclined that only the rear dips below the surface of the bath. If the precaution to heat the retort at the start in this manner be overlooked, it may sometimes happen that the sudden and violent expulsion of air through the liquid will carry portions of it bodily into the goose neck, and even into the condenser. With this point considered, the remainder of the operation presents no difficulty and requires little care.

The size of the retort may be suited, of course, to the particular case in hand, but for most purposes a 200 $cm.^3$ pipette makes a retort of convenient dimensions, neither too large for the distillation of small charges nor too small to permit the treatment of 100 $cm.^3$ of liquid comfortably. The tube of the goose neck should be wide enough to prevent the formation of bubbles in it; 0.7 cm. is a good measure for the interior diameter. It is of advantage to heat the bath to a point considerably above the temperature at which the liquid which is to be distilled boils — something between 130° C. and 140° C. does very well for water and is not too high for methyl alcohol — and under such circumstances, and when the retort is entirely submerged, it often happens that evaporation takes place with extreme rapidity from the surface of the liquid in perfect quiet without actual boiling.

With such an apparatus the following experiments were made. The boric acid was weighed, as before, in solution, and, to bring the condition of the experiment to that of an actual analysis, 1 grm. of pure sodium hydrate was added in solution, nitric acid or acetic acid to acidity and a little more, and the whole was introduced into the retort and distilled to dryness.

In those experiments in which nitric acid was employed, the methyl alcohol was introduced upon the residue thus dried in six successive portions of 10 cm.³ each and distilled to dryness; but in order to break up the residue of sodium nitrate, which by its insolubility might affect to some extent the protection of the boric acid from the action of the alcohol, 2 cm.³ of water were introduced and evaporated between the second and third and again between the fourth and fifth distillations.

When acetic acid was made use of to free the boric acid, the six distillations with methyl alcohol were made as before; but, sodium acetate being soluble in methyl alcohol, the intermediate treatments with water were unnecessary. With the fourth portion of methyl alcohol a few drops of acetic acid were added to preserve the acidity of the residue, which, as has been pointed out, tends to become alkaline under the treatment.

The residues of both processes of treatment were found to be free from boric acid by the exceedingly delicate test with turmeric, care being taken in the series of experiments in which nitric acid was used to oxidize nitrites by means of bromine (expelling the latter before making the test), and in the acetic acid series to acidify with hydrochloric acid sufficiently to counteract the tendency of the acetate by itself to brown the turmeric on evaporation.

The lime to retain the boric acid in the distillate was ignited in the crucible in which the evaporation of the distillate was to be made subsequently, and then transferred to the receiving flask attached to the condenser, so that the boric acid might be fixed during the distillation. To prevent the caking of the lime by the action of the alcohol, it was slaked with a little water before the distillation was begun.

In experiments (13) to (16) nitric acid was employed and in (17) to (20) acetic acid was used, with the precaution noted, to liberate the boric acid.

	B_2O_3 taken.	CaO taken.	B_2O_3+CaO found.	B_2O_3 found.	Error.
	grm.	grm.	grm.	grm.	grm.
(13)	0.1738	0.9647	1.1392	0.1745	0.0007+
(14)	0.1806	0.9639	1.1456	0.1817	0.0011+
(15)	0.1779	0.9665	1.1450	0.1785	0.0006+
(16)	0.1824	0.9739	1.1587	0.1848	0.0024+
(17)	0.1806	1.4559	1.6371	0.1812	0.0006+
(18)	0.1812	0.9720	1.1543	0.1823	0.0011+
(19)	0.1788	0.9986	1.1781	0.1795	0.0007+
(20)	0.1813	0.9527	1.1358	0.1831	0.0018+

In experiments (13) to (16) the mean error amounts to 0.0012+ grm.; in experiments (17) to (20) the mean error is a little more than 0.0010+ grm. Throughout the entire series of experiments the tendency to yield figures slightly larger than the truth is manifest, but the error is quite

within legitimate limits. The greatest care was taken to secure similarity of conditions under which the crucible and the lime were weighed before and after the evaporation and absorption of boric acid, and the weight after ignition was taken in every case after cooling over sulphuric acid during a definite period of ten minutes, in order to eliminate as far as possible the effect of atmospheric condensation upon the large surface of platinum. Ignitions were always finished over the blast lamp, and constancy of weights was secured.

The results indicate that both modes of treatment are on the whole equally satisfactory.

In the presence of chlorides, it is of course impossible to employ nitric acid to free the boric acid. Oxalic, citric, and tartaric acids also liberate hydrochloric acid to a considerable extent from alkaline chlorides. It was found, however, that when acetic acid was distilled over sodium and potassium chlorides only traces of hydrochloric acid passed into the distillate, and experiments (21) to (23) were made to determine whether these amounts are sufficient to vitiate the separation of boric acid from alkaline chlorides by distillation in presence of free acetic acid. The details of treatment were identical with those of experiments (17) to (20), excepting only the addition of 0.5 grm. of sodium chloride to each portion before distillation.

	B_2O_3 taken.	CaO taken.	B_2O_3+CaO found.	B_2O_3 found.	Error.
	grm.	grm.	grm.	grm.	grm.
(21)	0.1834	0.9842	1.1675	0.1833	0.0001−
(22)	0.1831	0.9755	1.1593	0.1838	0.0007+
(23)	0.1761	0.9740	1.1523	0.1783	0.0022+

The mean error of these results is about 0.0009+ grm., and it is plain that the presence of sodium chloride does not materially change the conditions of the experiment. There seems, therefore, to be no reason why boric acid may not be separated by distillation from alkaline chlorides in presence of free acetic acid; but it was found that the presence of any considerable amount of potassium acetate is disadvantageous. Sodium acetate to a reasonable amount does not interfere with the favorable progress of the separation; but potassium acetate appears to require a much higher temperature for the expulsion of its water, and longer distillation.

When, therefore, chlorides are present in the salts from which boric acid is to be removed by distillation, the choice is open between two methods. The distillation may be made directly with an excess of acetic acid; or the hydrochloric acid may be first removed by means of silver nitrate and the distillation of the filtrate proceeded with at once or after precipitation of the excess of silver salt by means of sodium hydrate or carbonate, care being taken to acidify again sufficiently with nitric acid after the removal of the silver. Of these two modes of proceed-

ing, I incline to the treatment with nitric acid and the removal of the chlorine by precipitation; and this method has been used with success by others as well as myself for some months in the analysis of waters carrying boric acid and natural borates.

The process in either modification is fairly accurate and easily executed and admits of very wide application. Insoluble compounds in which the boric acid is to be determined may be dissolved in nitric acid at once, or, if necessary, first fused with sodium carbonate; and, fortunately, nearly everything which is volatile in the subsequent treatment and capable of forming with lime compounds not easily decomposable by heat may be removed by known processes. The combination of fluorine, silica, and boric acid is perhaps most difficult to treat; but the precipitation and removal of the first as calcium fluoride from the aqueous solution of a fusion in alkaline carbonate may, it is believed, be effected with care, and the mode of procedure from that point is simple.

The number of distillations necessary depends, of course, upon the amount of boric acid treated. To remove 0.2 grm. of boric anhydride completely to the distillate, six charges of methyl alcohol, of 10 $cm.^3$ each, proved, as we have seen, to be ample.

The apparatus by the aid of which the distillation processes which have been described were carried out has found useful application in a number of other processes. In the determination of free and albuminoid ammonia in waters which can be boiled quietly with difficulty, in the methods of estimating hydrofluoric acid which involve the expulsion of silicon fluoride from a mixture of the fluoride with sulphuric acid and silica, in the separation of iodine from bromides and chlorides by distilling with ferric sulphate and sulphuric acid and of bromine from chlorides by means of permanganic acid, it has proved of value, and it will doubtless be found convenient in many analytical processes in which quantitative separations by the distillation of liquids liable to spatter or boil explosively are involved.

A METHOD FOR THE SEPARATION OF SODIUM AND POTASSIUM FROM LITHIUM BY THE ACTION OF AMYL ALCOHOL ON THE CHLORIDES, WITH SOME REFERENCE TO A SIMILAR SEPARATION OF THE SAME FROM MAGNESIUM AND CALCIUM.

By F. A. Gooch.

For the quantitative separation of lithium from sodium and potassium Mayer's method,[1] which is based upon the precipitation of lithium as the tribasic phosphate, and Rammelsberg's[2] mode of parting the chlorides by means of a mixture of anhydrous alcohol and ether in equal parts have been available.

The method of Mayer grew out of the older process of Berzelius,[3] which consisted essentially in treating the solution of the alkaline salts with phosphoric acid and sodium carbonate in excess, evaporating to dryness, and extracting with cold water. The result of a single analysis of the product thus obtained was the testimony upon which Berzelius rested the belief and statement that the salt was a double phosphate of lithium and sodium, which left upon ignition sodium and lithium pyrophosphates in equal molecules; and on this Berzelius based his process for the estimation of lithium. Rammelsberg,[4] however, showed later that it was a tribasic phosphate which was actually obtained, and from his experiments arrived at the conclusion that the proportions of soda and lithia were variable within wide limits, the amounts of the former varying in the special cases investigated from 7.84 per cent. to 28.38 per cent.; and the same thing in substance was reiterated subsequently[5] in an account of a repetition of the work suggested by the criticism of Mayer. Mayer,[6] however, was unable to prepare under any conditions the double phosphate of Rammelsberg, and obtained invariably, when the preparation had been washed with sufficient care, trilithium phosphate free from sodium; but the point was made that the phosphate is apt to be contaminated with lithium carbonate when sodium carbonate is employed to bring about alkalinity.

[1] Ann. Chem. u. Pharm., XCVIII, p. 193.
[2] Pogg. Ann., LXVI, 79.
[3] Id., IV, 245.
[4] Loc. cit.
[5] Pogg. Ann., CII, 443.
[6] Loc. cit.

Mayer therefore modifies the method of Berzelius by substituting sodium hydrate for the carbonate, and, proceeding, evaporates to dryness, treats the dry mass with as much water as is needed to dissolve the soluble salts with the aid of heat, adds a drop or two of sodium hydrate if necessary to restore alkalinity, and then ammonia in volume equal to that of the water already added, sets aside at a gentle heat, filters only after twelve hours, and washes with a mixture of ammonia and water in equal parts. From the filtrate and first washings a small amount of the lithium phosphate is to be recovered by evaporation and the repetition of the former treatment. According to Mayer the precipitation of the phosphate may be effected with equal completeness by boiling the solution, prepared as before, instead of evaporating it; but the objection to this mode of proceeding is the tendency of the liquid carrying the precipitate to bump explosively. Careful washing, somewhat prolonged, is essential to secure the complete removal of salts of sodium and potassium, and it is remarked that the purity of the precipitate is shown by its failure to cake when strongly ignited.

This is the mode of proceeding by which Mayer separates lithium from sodium and potassium, isolating it as presumably pure trilithium phosphate and weighing it as the anhydrous salt. In dealing with mixtures of the chlorides in which the proportion of the lithium salt is relatively small, the removal of the greater part of sodium and potassium chlorides by a preliminary treatment with absolute alcohol is recommended. The following table comprises the results of Mayer's test analyses of lithium carbonate in the first seven, of lithium sulphate in the last two, recalculated with the use of the number 7 — the figure now generally accepted — as the atomic weight of lithium.

Li_3PO_4 equivalent to salt taken.	Li_3PO_4 found.	Error.
grm.	grm.	grm.
1.3586	1.3719	0.0133+
1.5172	1.5088	0.0084−
0.7519	0.7580	0.0061+
0.9561	0.9510	0.0051−
1.2651	1.2646	0.0005−
1.2197	1.2230	0.0033+
0.8991	0.9018	0.0027+
1.1325	1.1236	0.0089−
0.9715	0.9665	0.0050−

Fresenius[1] found on examining the method that several repetitions of the treatment by evaporation and extraction were required to complete the recovery of all lithium phosphate, and advised that the operation be continued until residual lithium phosphate fails to appear. The results of Fresenius's experiments with lithium carbonate, recalculated

[1] Zeitschr. anal. Chem., I, p. 42.

with the use of the number 7 as the atomic weight of lithium, are given in the table appended.

Li_3PO_4 equivalent to salt taken.		Li_3PO_4 found. Dried at 100° C.	Ignited.	Error.
grm.		grm.	grm.	grm.
0.7443	after two treatments	0.7243	......	0.0200 —
	" three "	0.7385	......	0.0058 —
	" four "	0.7433	......	0.0010 —
0.9820		0.9861	......	0.0041+
		......	0.9826	0.0006+
1.6341		1.6342	......	0.0001+
		......	1.6305	0.0036 —

Thus it will be seen that in the nine experiments of Mayer the error ranges from 0.0133+ grm. to 0.0089 — grm., and that of the determinations of Fresenius from 0.0001+grm. to 0.0041+grm. for the dried precipitate and from 0.0006+ grm. to 0.0036 — grm. for the ignited precipitate.

If the tendency of lithium carbonate to fall in company with the phosphate were not to assert itself during the evaporations of solutions of salts of lithium in presence of sodium hydrate and in contact with ordinary atmospheric air, it would surely be strange, and this point may be fairly set down as one of the weak ones of the method; but the gravest source of error, and that indicated most unmistakably throughout the whole history of the process — which has been recounted at some length for the purpose of emphasizing this very matter—is the impossibility of preparing the lithium phosphate in anything like a condition of freedom from other alkaline phosphates without a careful and prolonged washing, which is sure to result in loss of the lithium salt by solution. When it is remembered that according to Mayer's determinations trilithium phosphate requires for solution only 2,539 parts of water or 3,920 parts of a mixture of ammonia and water in equal portions, it is plain that the success of the method depends upon the ability of the analyst to wash to a condition of purity, and without loss of that which it is the purpose of the process to save, a precipitate peculiarly prone to retain foreign matter and soluble in the washing mixture in the proportion of 10 milligrams to every 40 $cm.^3$ of the latter. Of course washings will never be entirely saturated, nor will the precipitate be as soluble at the beginning of the operation as at the end, when the precipitant no longer exerts an action which tends to lessen solubility; but in view of the difficulties which present themselves, it is sufficiently obvious that exact results obtained by Mayer's process owe their apparent accuracy to a fortuitous balance of errors. The difference of 0.0222 grm. between the extremes of Mayer's experimental results should not be surprising; and, at the best, the process is tedious and not entirely trustworthy, facts of which its author was not unmindful.

In Rammelsberg's method of separating lithium chloride from the chlorides of sodium and potassium the sources of error are, in brief, the solubility of sodium chloride and potassium chloride in the ether-alcohol mixture, the influence which the presence of small amounts of water exerts upon the solubility of these same salts, the difficulty of bringing the chlorides to the anhydrous condition without decomposing the lithium chloride to a greater or less extent, and the mechanical difficulties of transferring the fused or crusted chlorides to a suitable receptacle for digestion and agitation in the solvent, and of extracting perfectly the soluble constituents of closely compacted matter. Of the last two items nothing need be said in explanation beyond simply noting them. The third is particularily important, inasmuch as the tendency of lithium chloride, first noted I believe by Mayer, to exchange chlorine for oxygen when ignited in presence of water, results in the formation of lithium hydrate or, in contact with products of combustion, lithium carbonate, both of which are insoluble in the mixture of ether and alcohol and remain with the sodium and potassium chlorides. As to the effect of water in the mixture, an experiment of Mayer, in which it was found that 100 cm.^{3} of a mixture of alcohol of 96 per cent. and ether of 98 per cent. dissolved 0.1100 grm. of sodium chloride, is instructive. In regard to the solubility of the chlorides of sodium and potassium in the mixture of anhydrous ether and alcohol, Rammelsberg's statement that from 0.9770 grm. of pure, strongly heated sodium chloride with an undetermined amount of lithium chloride the mixture extracted 0.0130 grm. is unfortunately meaningless in the absence of information concerning the amount of solvent employed. J. Lawrence Smith[1] found, in making an examination of this matter, that 10 cm.^{3} of the anhydrous ether-alcohol mixture extracted from 0.5 grm. of sodium chloride 0.0005 grm. and from 0.5 grm. of potassium chloride 0.0003 grm. Smith's mode of applying the method is better than the original; for, by taking care not to heat the mixed salts above 100° C., the danger of decomposing the lithium chloride is diminished, and by treating the dried salts with the ether-alcohol mixture in the capsule in which it is heated and weighed (protecting it by a small inverted bell glass) the disadvantage of the transfer is avoided, but the danger is incurred that the mixed salts may not be thoroughly dried by heat so gentle. With this modification Smith obtained results which are rearranged in the following statement, and which do not throw a very favorable light upon the method:[2]

[1] Am. Jour. Sci. (2), XVI, p. 56.

[2] Dr. Smith's language in the description of these experiments is somewhat ambiguous, but it is believed that these figures represent the meaning intended. After the presentation of the data of the first experiment given here with the correction of an obvious typographical error, it is said of the second and third experiments that "a similar mixture containing 18.10 per cent. of chloride of lithium furnished a residue of 17.65 per cent." and "a similar mixture containing 67.20 per cent. of chloride

NaCl taken. grm.	KCl taken. grm.	LiCl taken. grm.	Weight dissolved. grm.	Error. grm.
0.2000	0.2000	0.0080	0.0101	0.0021+
0.2000	0.2000	0.0884	0.0862	0.0022−
0.2000	0.2000	0.8195	0.8341	0.0146+

It is obvious, therefore, that neither the method of Rammelsberg nor that of Mayer may justly claim to be what a good process should be, accurate and rapid; and in the dilemma many chemists have been inclined to accept, with Bunsen,[1] the inherent disadvantage of an indirect process, and in a mixture of sodium and lithium chlorides calculate the percentage of each from the known weight of the mixture and its contents in chlorine, and in a mixture of the three chlorides calculate the percentage of each from the known weight of the mixture and the determined contents in chlorine and potassium. Here again, however, as in Rammelsberg's process, the difficulty of bringing the chlorides to a definite condition for weighing without decomposing the lithium chloride is an obstacle; and in case potassium is to be separated from large amounts of lithium by precipitation as potassio-platinic chloride, the concurrent precipitation of a similar salt of lithium, to which Jenzsch[2] has directed attention, may be the occasion of inexactness. So, the intrinsic unsatisfactoriness of indirect methods quite aside, it appears that in following Bunsen we have by no means all that is to be desired in an analytical method.

In looking about for better means for the separation of lithium from sodium and potassium, certain preliminary experiments on the behavior of the chlorides of these elements toward amyl alcohol gave very encouraging indications, and subsequent quantitative tests have borne out the hope that a successful method of separation might be based upon these relations.

In amyl alcohol the chlorides of sodium and potassium are highly insoluble, lithium chloride dissolves freely, and the attraction of amyl alcohol for water is so slight and its boiling point so far above 100° C. that the latter may be expelled without difficulty by the aid of gentle heating.

When amyl alcohol is poured into a solution of lithium chloride in water the liquid forms two layers, the aqueous solution of the salts at the bottom and the amyl alcohol now carrying a little water above. With the application of heat, the water evaporates slowly, then boils, and, passing through the alcohol, escapes, until toward the end of the operation the residual lithium chloride collects in a viscous globule and

of lithium gave a residue of 68.40." I have taken this to mean that in all three experiments 0.2 grm. of sodium chloride and 0.2 grm. of potassium chloride were employed with the different proportions of lithium chloride indicated for each experiment. At all events, if this is not the meaning of the language made use of, it is difficult to see a definite value in the experiments.

[1] Ann. Chem. und Pharm., CXXII, p. 348.

[2] Pogg. Ann., CIV, p. 102.

finally dissolves, with the exception of a slight incrustation. If now the alcohol is cooled and a drop of strong hydrochloric acid is added and brought in contact with the deposit and the boiling repeated, the solution is complete. This deposit I take to be lithium hydrate, resulting from the decomposition of the chloride by the protracted action of water at a temperature near its boiling point. The small amount of water which is added in and with the hydrochloric acid seems to exert no unfavorable influence, but rather to be beneficial in hastening the solution of the residue by securing immediate and sufficient contact.

In hot amyl alcohol, lithium chloride appears to be a little more soluble than in the same reagent at ordinary temperatures, but the solubility under the latter condition only was determined. By boiling the solution until turbidity began to show, cooling, filtering, and then evaporating a known volume of the concentrated solution to dryness and weighing the residue after converting it to the sulphate, it was found that one part of lithium chloride was held dissolved in the cold in about fifteen parts of amyl alcohol, 10 cm.^{3} of the solution containing in the mean 0.66 grm. of the chloride.

When aqueous solutions of sodium chloride or potassium chloride are treated with amyl alcohol and boiled, the water disappears, as before, leaving first a globule of the concentrated solution and finally the crystalline salts. On continuing the boiling until a thermometer dipped in the liquid indicates the temperature at which the alcohol boils by itself, a slight additional precipitation, doubtless due to the expulsion of the water retained by the alcohol up to this point, takes place upon the walls of the containing vessel. The results of quantitative tests of the solubility of sodium and potassium chlorides are given in the following tables. The strengths of the solutions of sodium chloride and potassium chloride were determined by evaporating weighed portions in a platinum crucible and drying at a temperature considerably below the melting point of the salt, and weighing. The solution of lithium chloride was standardized by treating a weighed portion with sulphuric acid in excess, evaporating, igniting at red heat, and weighing. The standards were fixed by experiments (1) to (9).

	Weight of solution of NaCl taken.	Weight of NaCl found.	Weight of NaCl in 10 grm. of solution.	Mean.
	grm.	grm.	grm	
(1)	10.7110	0.1072	0.1001	grm.
(2)	10.9419	0.1097	0.1003	0.1002
(3)	10.9325	0.1097	0.1003	

	Weight of solution of KaCl taken.	Weight of KaCl found	Weight of KaCl in 10 grm. of solution.	Mean.
	grm.	grm.	grm.	
(4)	9.3045	0.1744	0.1874	grm.
(5)	10.7225	0.2006	0.1871	0.1872
(6)	11.1974	0.2096	0.1872	

	Weight of solution of LiCl taken.	Weight of Li_2SO_4 found.	Weight of LiCl in 10 grm. of solution.	Mean.
	grm.	grm.	grm.	grm.
(7)	10.9280	0.1635	0.1156	
(8)	11.1480	0.1665	0.1153	0.1154
(9)	10.8790	0.1626	0.1154	

To determine the solubility of sodium chloride and potassium chloride in amyl alcohol, portions of the test solutions were weighed out, evaporated to a convenient bulk in platinum crucibles of 100 cm.^{3} capacity, amyl alcohol was added, the water expelled by boiling, and the heating continued for some minutes after the thermometer in the liquid indicated 132° C., the boiling point of the alcohol employed. The liquid was then decanted with care and the residue dried at a temperature below its melting point and weighed. When the chlorides are precipitated in the manner described, the deposit generally adheres so closely and such particles as do remain loose settle so well that the supernatant liquid may be decanted to the end without appreciable transportation of the insoluble residue. For the sake of perfect security, however, in this part of the manipulation the decanted liquid was filtered under gentle pressure upon asbestus, with the aid of the device which I have previously described for such purposes,[1] and, after gentle heating, the increase in weight of the felt and the containing perforated crucible was added to the weight of the residual salt. In no case did this increase exceed a few tenths of a milligram and often could not be detected.

As a source of heat, a bath in which the sand of the sand bath is replaced by smooth asbestus board is a convenience, or a piece of asbestus board simply, about 30 cm. square, supported by a broad tripod and heated under the middle by a Bunsen burner, answers equally well to secure every gradation of heat without danger of igniting the evaporated alcohol.

As a control upon the results obtained by weighing the residue as described, the filtrate was evaporated in a large platinum crucible and the residue thus left gently heated and weighed. Though the evaporation be conducted with extreme care, the residue is almost sure to show some blackening, due to the carbonization of matter carried by the alcohol, which will not disappear entirely without the application of a degree of heat which the salts cannot bear without danger of volatilization. The weight of the residue from the amyl alcohol itself is small, one portion of 50 cm.^{3} yielding 0.0003 grm. and its mate 0.0007 grm., so that the data obtained by the evaporation of the filtered alcohol of the experiments, if not quite so trustworthy as the former testimony,

[1] Proc. Am. Acad., Vol. XIII, p. 342.

may nevertheless serve the purpose of a very close control. Both sets of data are given in the following table:

	Weight of NaCl taken.	Total weight of NaCl found.	Weight found in residue.	Weight found in solution.	Volume of residual amyl alcohol.
	grm.	grm.	grm.	grm.	cm.^{3}
(10)	0.1062	0.1067	0.1043	0.0024	52
(11)	0.1043	0.1047	0.1024	0.0023	46
(12)	0.1024	0.1030	0.1003	0.0027	51
(13)	0.1003	0.1008	0.0983	0.0025	45

Reducing these figures to a common level to show the action of the same amount of amyl alcohol in every case we have:

	Loss of NaCl to 100 cm.^{3} of amyl alcohol.	Mean.	Weight of NaCl found in solution in 100 cm.^{3} of amyl alcohol.	Mean.
	grm.		grm.	
(10)	0.0037	grm. 0.0041	0.0046	grm. 0.0051
(11)	0.0041		0.0050	
(12)	0.0041		0.0053	
(13)	0.0044		0.0055	

	Weight of KCl taken.	Total weight of KCl found.	Weight found in residue.	Weight found in solution.	Volume of residual amyl alcohol.
	grm.	grm.	grm.	grm.	cm.^{3}
(14)	0.2091	0.2093	0.2074	0.0019	35
(15)	0.2074	0.2078	0.2059	0.0019	36
(16)	0.2059	0.2059	0.2040	0.0019	32
(17)	0.2040	0.2041	0.2015	[illegible]	45

Derived from these figures we have:

	Loss of KCl to 100 cm.^{3} of amyl alcohol.	Mean.	Weight of KCl found in solution in 100 cm.^{3} of amyl alcohol.	Mean.
	grm.		grm.	
(14)	0.0049	grm. 0.0051	0.0054	grm. 0.0056
(15)	0.0041		0.0053	
(16)	0.0059		0.0059	
(17)	0.0056		0.0058	

From these figures it appears that the total weight of chloride found is always a little greater than that taken, the mean increase being 0.0005 grm. for sodium chloride and 0.0002 grm. for potassium chloride. It appears also that the residue left by the evaporation of the decanted and filtered amyl alcohol is greater than the loss put upon the chloride by the treatment: in the case of sodium chloride 0.0005 grm., in the mean, for every 50 cm.^{3} of amyl alcohol, which is about the quantity employed in the experiments; for potassic chloride 0.0002 grm., in the mean, for 40 cm.^{3} of amyl alcohol, which is approximately the quantity

used in that case. It will be seen, therefore, that there exists for both salts an exact coincidence between the mean total excess found and the difference between the figures which indicate the solubility of the salts for the two methods of determination; and, taking this fact in conjunction with the results of the evaporation of amyl alcohol in blank (the mean residue being 0.0004 grm. for 40 cm.^{3}, and 0.0005 grm. for 50 cm.^{3}), it seems to be brought out pretty clearly that the former set of figures represents more exactly the solubility of the salts, though the difference between the two series is not great. Resting, then, upon the former determinations, the solubility of sodium chloride may be taken as 0.0041 grm. in every 100 cm.^{3} of anhydrous amyl alcohol, or one part in 30,000 parts by weight; and the solubility of potassium chloride, a little greater, is 0.0051 grm. to 100 cm.^{3} of amyl alcohol, or one part in 24,000 by weight.

The conditions under which the salts are acted upon are such as should insure the complete saturation of the solvent, and in this connection it is interesting to note that for the quantities of material employed the discrepancy between comparable figures never exceeds 0.0005 grm.

In experiments (10), (11), and (14), (15), the alcohol was decanted and filtered at once while hot; in (12), (13), and (16), (17), it was cooled to 30° C. before decanting; so it appears that the solubility of the salts is not influenced by changes of temperature within the range from 30° C. to 132° C.

Used simply to wash the precipitate, amyl alcohol cannot, of course, exert an effect at all comparable with that manifested in the experiments which have been described, but to know just what this action may be is important. Experiments (18) to (22) were undertaken, therefore, to elucidate this point.

Weighed amounts of the test solutions were evaporated nearly to saturation in small glass beakers, amyl alcohol added, and, as in the previous experiments, the whole heated until the salt had deposited and the residual alcohol had boiled quietly for some minutes at its ordinary boiling point, the liquid decanted, filtered under gentle pressure by means of a weighed perforated crucible and felt of asbestus, the filtrate measured, the residue dislodged with the aid of a rubbing-rod and transferred to the crucible and washed with anhydrous amyl alcohol, the washings being collected and measured. The crucible and contents were dried over a free flame turned low, so that the heat should not reach the melting point of the chlorides.

	Weight of NaCl taken.	Weight of NaCl found.	Weight of NaCl found, corrected for solubility in residual amyl alcohol.	Error of corrected weight of NaCl found.	Volume of residual amyl alcohol.	Volume of amyl alcohol in washings.
	grm.	grm.	grm.	grm.	cm.^{3}	cm.^{3}
(18)	0.0947	0.0937	0.0947	0.0000	24	44
(19)	0.1080	0.1074	0.1083	0.0002+	19	53

	Weight of KCl taken.	Weight of KCl found.	Weight of KCl found, corrected for solubility in residual amyl alcohol.	Error of corrected weight of KCl found.	Volume of residual amyl alcohol	Volume of amyl alcohol in washings.
	grm.	grm.	grm.	grm.	$cm.^3$	$cm.^3$
(20)	0.1846	0.1837	0.1847	0.0001+	20	60
(21)	0.1964	0.1946	0.1961	0.0003−	30	45
(22)	0.1857	0.1839	0.1854	0.0003−	30	60

These results show very plainly that the solvent effect of anhydrous amyl alcohol used for washing under the conditions described is trifling in the extreme, and may be neglected utterly providing the amount of the washing is not altogether disproportionate to the needs of the case.

We pass next to the consideration of the separation of the chlorides of sodium and potassium from lithium chloride. Weighed portions of the test solutions were concentrated and treated with amyl alcohol in the manner described until the precipitated salt was entirely free from water and the supernatant alcoholic solution of the lithium chloride boiled constantly at a point not far from that of the amyl alcohol employed. Then the liquid was cooled, a drop or two of strong hydrochloric acid was added in accordance with the evident suggestion of the preliminary experiments previously mentioned, and heat was again applied until the boiling had continued, as before, for some minutes at one point. The filtration, washing, drying, and weighing of the residue were effected as in experiments (18) to (22). In those of the experiments in which the lithium salt in solution was also determined, the end was accomplished by evaporating the filtrate and washings to dryness, treating the residue with sulphuric acid, and igniting and weighing as lithium sulphate. In the following table the weight of insoluble chloride actually found is given in one column, and this weight, corrected according to the data previously determined for the solubility of the chloride in the residual amyl alcohol, appears in the column adjoining. So also the weight is given of the lithium sulphate actually found, and an adjacent column contains the result of correcting this weight for the accompanying sodium or potassium sulphate, or both, upon the hypothesis that these salts are neutral sulphates after the ignition. In the case of quantities so minute the error which is introduced by such an assumption cannot be considerable, and in relation to this point Dittmar[1] maintains that comparatively large amounts of acid sodium or potassium sulphate may be reduced to the neutral salt by ignition simply. The figures of the column showing the weights of lithium chloride found are derived by calculation from the weights of lithium sulphate actually

[1] Report on researches into the composition of ocean water, collected by H. M. S. Challenger during the years 1873-1876, p. 18.

found. The other headings of the table are sufficiently intelligible without further explanation.

	Weight of NaCl taken.	Weight of NaCl found.	Weight of NaCl found, corrected for solubility in amyl alcohol.	Error in weight of NaCl found.	Error in corrected weight of NaCl found.	Volume of amyl alcohol used. Residual.	Total.
	grm.	grm.	grm.	grm.	grm.	cm.³	cm.³
(23)	0.1089	0.1092	0.1095	0.0003+	0.0006+	7	70
(24)	0.1084	0.1085	0.1090	0.0001+	0.0006+	12	80
(25)	0.1074	0.1067	0.1074	0.0007−	0.0000	18	90

	Weight of LiCl taken.	Weight of Li_2SO_4 found.	Weight of LiCl found.	Corrected weight of LiCl found.	Error in weight of LiCl found.	Error in corrected weight of LiCl found.
	grm.	grm.	grm.	grm.	grm.	grm.
(23)	0.1298	0.1682	0.1299	0.1296	0.0001+	0.0002−
(24)	0.1227	0.1592	0.1230	0.1225	0.0003+	0.0002−
(25)	0.0116	....	....	....	....	....

	Weight of KCl taken.	Weight of KCl found.	Weight of KCl found, corrected for solubility in amyl alcohol.	Error in weight of KCl found.	Error in corrected weight of KCl found.	Volume of amyl alcohol used. Residual.	Total.
	grm.	grm.	grm.	grm.	grm.	cm.³	cm.³
(26)	0.2051	0.2036	0.2053	0.0015−	0.0002+	34	100
(27)	0.2022	0.2013	0.2032	0.0009−	0.0010+	37	100
(28)	0.2109	0.2096	0.2104	0.0013−	0.0005−	16	100
(29)	0.0984	0.0970	0.0980	0.0014−	0.0004−	20	90

	Weight of LiCl taken.	Weight of Li_2SO_4 found.	Weight of LiCl found.	Corrected weight of LiCl found.	Error in weight of LiCl found.	Error in corrected weight of LiCl found.
	grm.	grm.	grm.	grm.	grm.	grm.
(26)	0.1256	0.1638	0.1265	0.1248	0.0009+	0.0008−
(27)	0.1287	0.1677	0.1296	0.1277	0.0009+	0.0010−
(28)	0.0113	....	....	....	....	....
(29)	0.0113	....	....	....	....	....

	Weight of NaCl taken.	Weight of KCl taken.	Weight of NaCl + KCl found.	Corrected weight of NaCl + KCl found.	Volume of amyl alcohol used. Residual.	Total.
	grm.	grm.	grm.	grm.	cm.³	cm.³
(30)	0.1053	0.1031	0.2064	0.2084	22	100
(31)	0.1051	0.0945	0.1988	0.2003	16	80

	Weight of LiCl taken.	Error in weight of NaCl + KCl found.	Error in corrected weight of NaCl + KCl found.
	grm.	grm.	grm.
(30)	0.0113	0.0020−	0.0000
(31)	0.0113	0.0008−	0.0007+

It will be noticed that in experiments (23), (24), (26), and (27) the corrected error in the weight of the insoluble chloride has a positive

value, ranging from 0.0002+ grm. to 0.0010+ grm., with a mean of 0.0006+ grm.; and that in experiments (25), (28), (29), (30), and (31), the mean error is negative, amounting to less than 0.0001− grm., with a range from 0.0005− grm. to 0.0007+ grm.

The point of difference between these two series of experiments is the amount of lithium chloride introduced, only a tenth of that used in the former being employed in the latter. It is plain that, when we are dealing with the larger amount, a larger portion tends to remain behind with the insoluble chloride; and here again we meet, though to a degree comparatively harmless, the inclination of lithium chloride to yield chlorine and pass to the form of lithium hydrate. When the lithium chloride is present in small amount, as in the latter group of experiments, there can be little left undissolved; and the spectroscope confirms the evidence of the figures of analysis as to the perfectness of the separation by showing in such cases either no lithium at all or merely fugitive traces. If a single precipitation is sufficient to effect a satisfactory separation of the insoluble chlorides from small amounts of lithium chloride, it is natural to suppose that a repetition of the precipitation would be beneficial in treating larger quantities of lithium chloride.

Experiments (32) to (37) illustrate the effect of a double precipitation. The chlorides were brought to filtration as before, the liquid was decanted as completely as possible, the precipitate washed slightly by decantation and redissolved in a little water, and the round of boiling, filtering, drying, and weighing carried to the end as before, care being taken to repeat the treatment with a drop of hydrochloric acid during the process of boiling. The two portions of residual amyl alcohol were measured apart, as well as the washings.

	Weight of NaCl taken.	Weight of NaCl found	Corrected weight of NaCl found.	Error in weight of NaCl found.	Error in corrected weight of NaCl found.	Volume of amyl alcohol used. Residual. I.	II.	Total.
	grm.	grm.	grm.	grm.	grm.	cm.^{3}	cm.^{3}	cm.^{3}
(32)	0.1166	0.1163	0.1169	0.0003−	0.0003+	8	8	150
(33)	0.1139	0.1127	0.1132	0.0012−	0.0007−	5	7	150

	Weight of LiCl taken.	Weight of Li_2SO_4 found.	Weight of LiCl found.	Corrected weight of LiCl found.	Error in weight of LiCl found.	Error in corrected weight of LiCl found.
	grm.	grm.	grm.	grm.	grm.	grm.
(32)	0.1287	0.1662	0.1284	0.1280	0.0003−	0.0007−
(33)	0.1347	0.1759	0.1359	0.1353	0.0012+	0.0006+

	Weight of KCl taken.	Weight of KCl found.	Corrected weight of KCl found.	Error in weight of KCl found.	Error in corrected weight of KCl found.	Volume of amyl alcohol used. Residual. I.	II.	Total.
	grm.	grm.	grm.	grm.	grm.	cm.^{3}	cm.^{3}	cm.^{3}
(34)	0.1155	0.1142	0.1152	0.0013−	0.0003−	10	10	100
(35)	0.1034	0.1017	0.1028	0.0017−	0.0007−	10	12	200
(36)	0.1914	0.1905	0.1912	0.0009−	0.0002−	3	11	90
(37)	0.1953	0.1939	0.1950	0.0014−	0.0003−	4	18	110

	Weight of LiCl taken.	Weight of Li_2SO_4 found.	Weight of LiCl found.	Corrected weight of LiCl found.	Error in weight of LiCl found.	Error in corrected weight of LiCl found.
	grm.	grm.	grm.	grm.	grm.	grm.
(34)	0.1125	0.1475	0.1139	0.1128	0.0014+	0.0003+
(35)	0.1251	0.1649	0.1274	0.1162	0.0023+	0.0011+
(36)	0.1263	......	......	......	....	....
(37)	0.1282	......	......	......	....	....

Thus it appears that, in the separation of the insoluble chlorides from the larger amounts of lithium chloride, the residue of two precipitations is substantially free from lithium.

For the sake of bringing the data in hand more directly into comparison, the corrected errors of the preceding determinations are tabulated again in the following statement:

No. of experiment.	Chloride.	Corrected error of insoluble chloride—			Error in corrected weight of LiCl.	Approximate mean error of LiCl.
		Precipitated once from about 0.13 grm. of LiCl.	Precipitated once from about 0.013 grm. of LiCl.	Precipitated twice from about 0.13 grm. of LiCl.		
		Grm.	Grm.	Grm.	Grm.	Grm.
(23)	NaCl	0.0006+	....	....	0.0002−	0.0005−
(24)	"	0.0006+	....	....	0.0002−	
(26)	KCl	0.0002+	....	....	0.0008−	
(27)	"	0.0010+	....	....	0.0010−	
(25)	NaCl	....	0.0000	....	....	
(28)	KCl	....	0.0005−	....	....	
(29)	"	....	0.0004−	....	....	
(30)	NaCl+KCl	....	0.0000	....	....	
(31)	" "	....	0.0007+	....	....	
(32)	NaCl	....	....	0.0003+	0.0007−	0.0003+
(33)	"	....	....	0.0007−	0.0006+	
(34)	KCl	....	....	0.0003−	0.0003+	
(35)	"	....	....	0.0007−	0.0011+	
(36)	"	....	....	0.0002−	....	
(37)	"	....	....	0.0003−	....	
	Approx. mean.	0.0006+	0.00004−	0.0003−		

Few processes in analytical chemistry are capable of yielding results more exact than these. The separation of from 0.1 grm. to 0.2 grm. of sodium or potassium chloride from a tenth of its own weight of lithium chloride is practically perfect in one operation, and from its own weight of lithium chloride the parting may be effected satisfactorily by two precipitations.

The points to be observed in executing the method may be recapitulated as follows:

To the concentrated solution of the chlorides, amyl alcohol is added and heat is applied, gently at first to avoid danger of bumping, until the water disappearing from solution and the point of ebullition rising

and becoming constant for some minutes at a temperature which is approximately that at which the alcohol boils by itself, the chlorides of sodium and potassium are deposited and lithium chloride is dehydrated and taken into solution. At this stage in the operation the liquid is cooled and a drop or two of strong hydrochloric acid is added to reconvert traces of lithium hydrate in the deposit, and the boiling is continued until the alcohol is again free from water. If the amount of lithium chloride present is small it will now be found in solution, and the chlorides of sodium and potassium will be in the residue, excepting the traces, for which correction will be made subsequently. If, however, the weight of lithium chloride present exceeds ten or twenty milligrams, it is advisable at this point, though not absolutely essential to the attainment of fairly correct results, to decant the liquid from the residue, wash the latter a little with anhydrous amyl alcohol, dissolve in a few drops of water, and repeat the separation by boiling again in amyl alcohol. For washing, amyl alcohol previously dehydrated by boiling is to be used and the filtrates are to be measured apart from the washings. In filtering it is best to make use of the perforated crucible and asbestus felt and apply gentle pressure. The crucible and residue are ready for the balance after drying for a few minutes directly over a flame turned low. The weight of insoluble chlorides actually obtained in this manner is to be corrected by the addition of 0.00041 grm. for every 10 cm.^{3} of amyl alcohol in the filtrate, exclusive of washings, if the insoluble salt is entirely sodium chloride, 0.00051 grm. for every 10 cm.^{3} if potassium chloride constitutes the residue, and, if both sodium and potassium chloride are present, 0.00092 grm.; but, as in the experiments described, the entire correction may in any case be kept within narrow limits, if due care be given to the reduction of the volume of residual alcohol before filtration. The filtrate and washings are evaporated to dryness, treated with sulphuric acid, the excess of the latter is driven off, and the residue ignited to fusion and weighed. From the weight thus found the subtraction of 0.00050 grm. is to be made if sodium chloride constitutes the precipitate, 0.00059 grm. if potassium chloride alone is present in the residue, and 0.00109 if both of these chlorides are present, for every 10 cm.^{3} of filtrate, exclusive of washings.

Amyl alcohol is not costly, the manipulations of the process are easy, and the only objectionable feature—the development of the fumes of amyl alcohol—is one which is insignificant when good ventilation is available.

The process has been used for some months frequently and successfully, by others as well as myself, for the estimation of lithium in waters and minerals.

In this connection it seems best to include the record of certain experiments looking to the separation of the chlorides of sodium and

potassium from the chlorides of magnesium and calcium. The behavior of magnesium chloride toward amyl alcohol is of interest, both with reference to the problem of separating sodium and potassium from lithium and magnesium when the latter are associated and as concerns the parting of the alkalies from magnesium alone — a matter which is by no means perfectly simple — and experiments (38) to (41) touch upon this topic.

The chlorides of sodium and potassium were weighed, as before, in solution; the magnesium chloride was obtained by dissolving in hydrochloric acid the oxide specially prepared and weighed as such. The process of treatment was identical with that just described for the separation of the chlorides of potassium and sodium from lithium chloride.

	Weight of NaCl taken.	Weight of KCl taken.	Weight of NaCl+KCl found.	Corrected weight of NaCl+KCl found.	Volume of amyl alcohol used. Residual. I.	II.	Total.
	grm.	grm.	grm.	grm.	cm.³	cm.³	cm.³
(38)	0.1030	0.1064	0.2079	0.2100	23	..	120
(39)	0.0967	0.1024	0.1976	0.2006	33	..	100
(40)	0.1030	0.1073	0.2071	0.2093	13	11	100
(41)	0.1053	0.1093	0.2114	0.2142	12	18	100

	Weight of MgO taken.	Error in weight of NaCl+KCl found.	Error in corrected weight of NaCl+KCl found.
	grm.	grm.	grm.
(38)	0.1000	0.0015—	0.0006+
(39)	0.1000	0.0015—	0.0015+
(40)	0.1000	0.0032—	0.0010—
(41)	0.1000	0.0032—	0.0004—

The residues of experiments (38) and (39), in which the separation was made by a single precipitation, carried traces of magnesia; those of (40) and (41), in which two precipitations were introduced, were found to contain in the one case no magnesia and in the other an unweighable trace. These results point out a method by which the chlorides of sodium and potassium may be obtained free from magnesia, while the small amounts of the former which pass into solution with the magnesium chloride are capable of accurate estimation; and there seems to be no reason why the separation of these alkaline chlorides from magnesium chloride and lithium chloride occurring together should not be effected in one operation, and the parting of the latter salts brought about by the familiar method of precipitating the magnesium in the cold as ammonium-magnesium phosphate.

Experiments (42) to (47), upon the separation of sodium and potassium from calcium by the action of amyl alcohol on the chlorides, yielded the figures of the following table. The mode of treatment was identical with that of the experiments with magnesia just described, excepting

only the substitution of pure calcium oxide, specially prepared, for magnesium oxide.

	Weight of NaCl taken.	Weight of KCl taken.	Weight of NaCl+KCl found.	Corrected weight of NaCl+KCl found.	Volume of amyl alcohol used. Residual. I.	II.	Total.
	grm.	grm.	grm.	grm.	cm.³	cm.³	cm.³
(42)	0.0850	0.1126	0.2177	0.2195	20	..	100
(43)	0.1018	0.1057	0.2217	0.2235	20	..	100
(44)	0.1096	0.0962	0.2112	0.2130	20	..	100
(45)	0.0985	0.1018	0.2113	0.2130	19	..	100
(46)	0.0914	0.1104	0.1968	0.2000	20	15	100
(47)	0.0997	0.1100	0.2080	0.2089	3	7	90

	Weight of CaO taken.	Error in weight of NaCl+KCl found.	Error in corrected weight of NaCl+KCl found.
	grm.	grm.	grm.
(42)	0.1000	0.0192+	0.0210+
(43)	0.1000	0.0142+	0.0160+
(44)	0.1000	0.0054+	0.0072+
(45)	0.1000	0.0110+	0.0127+
(46)	0.1000	0.0050−	0.0018−
(47)	0.1000	0.0017−	0.0008−

From these results it is plain that it is a far more difficult matter to dehydrate and dissolve calcium chloride than to dehydrate and dissolve either magnesium chloride or lithium chloride. The separation of the chlorides of sodium and potassium from calcium chloride cannot be accomplished, for the quantities employed in these experiments, by a single precipitation; but the repetition of the treatment is effective. In the residues of experiments (46) and (47) calcium could not be found by the test with ammonium oxalate. In a case, therefore, in which the separation of sodium and potassium from lithium, magnesium, and calcium in one operation should be desirable, the end may probably be accomplished by means of the process here described.

Certain preliminary experiments with the nitrates of the bases under discussion indicate that these are susceptible of similar separation by the action of amyl alcohol; and the wide applicability in analytical operations of the general principle involved — the dehydrating of salts by means of amyl alcohol or other liquid of high boiling point and appropriate solvent action — can scarcely be a matter of doubt.

THE INDIRECT ESTIMATION OF CHLORINE, BROMINE, AND IODINE BY THE ELECTROLYSIS OF THEIR SILVER SALTS, WITH EXPERIMENTS ON THE CONVERTIBILITY OF THE SILVER SALTS BY THE ACTION OF ALKALINE HALOIDS.

By J. EDWARD WHITFIELD.

In the absence of trustworthy methods for the direct quantitative separation of bromine and chlorine, it is usual to employ some process for the conversion of the mixed silver salts to a common condition. Both the reduction to silver by hydrogen and the conversion of the bromide to chloride by heating in an atmosphere of chlorine are attended with loss by volatilization and mechanical transfer, and the possible inaccuracy of both the processes is such that they can scarcely be considered as available for the estimation of small amounts of either constituent in the presence of large amounts of the other.

Of all such methods the electrolytic analysis of the mixed and fused silver salts as proposed by Bolley[1] and more recently introduced and tested by Kinnicutt[2] is probably the best, though according to Finkener[3] perfect decomposition is difficult to obtain by this method and there is danger of volatilization and partial change of the silver salts in the fusion.

Kinnicutt's test analyses of the fused salts show, for silver chloride and silver bromide each by itself, errors of 0.0006 − grm. to 0.0003 + grm. on amounts varying from 0.7 grm. to 1.8 grm.; and for the mixed silver chloride and bromide errors from 0.0010 − grm. to 0.0012 + grm. with a mean of 0.0006 + grm. on weights varying from 2 grm. to 2.8 grm.

These figures represent the sum of the errors from the weighing of the fused chloride to the weighing of the deposit of silver and do not include errors made in the precipitation, filtration, transfer to the crucible, and fusion.

A method in which the decomposition of the silver salts may be effected without fusion, and which would at the same time place the errors of filtration, preparation for weighing, and subsequent electrolysis at a

[1] Dingl., Pol. Jour., CLI, p. 46.
[2] Am. Chem. Jour., IV, p. 22.
[3] Rose-Finkener, Quant. Anal., II, p. 621.

minimum, seems to be desirable, and a promising line of investigation was suggested by Luckow's assertion[1] that from the solution of silver chloride in potassium cyanide the silver may be thrown down completely.

Luckow gives no figures, excepting a common mean of all determinations by the precipitation from the cyanide solution and the decomposition of the solid chloride on the negative pole of the battery under sulphuric acid; so that the first experiments were made to test the accuracy of the battery process under these conditions.

In experiments (1) to (5) silver chloride was the starting point. In (1) to (3) the freshly precipitated and carefully washed chloride was dried to a constant weight in a platinum dish, protected from the light, at a temperature of about 150° C., dissolved in potassium cyanide and electrolyzed after the addition of a little sodium hydrate, preliminary analyses having seemed to indicate that the presence of sodium hydrate affected the deposition favorably. In all subsequent experiments ammonia, which was found to be of equal service, was used instead of sodium hydrate.

In experiments (4) and (5) the chloride was converted, previous to electrolysis, into the bromide by solution in potassium cyanide, the addition of potassium bromide, and precipitation by sulphuric acid, as will be described later, and the precipitate redissolved in potassium cyanide, the object being to test the action of the battery upon the cyanide solution of the silver bromide.

	Ag Cl taken.	Silver found.	Silver calculated.	Error.
	grm.	grm.	grm.	grm.
(1)	0.1565	0.1177	0.1178	0.0001 —
(2)	1.3004	0.9785	0.9787	0.0002 —
(3)	2.2657	1.7047	1.7051	0.0004 —
(4)	0.7472	0.5618	0.5624	0.0006 —
(5)	0.2854	0.2133	0.2147	0.0014 —

These results, as far as they go, are satisfactory. Similar tests upon the electrolysis of silver bromide and silver iodide in the cyanide solution were undertaken, but it was thought advisable to combine incidentally with the tests of the battery process an examination of the method recently proposed by Maxwell-Lyte[2] for the direct conversion of silver chloride to the bromide and thence to the iodide.

Field[3] was the first to propose a quantitative conversion of silver chloride to the bromide by digesting the former in potassium bromide, and the change of the chloride or bromide to the iodide by the action of potassium iodide upon these salts. This method has been variously criticised and finally abandoned as an inaccurate process,[4] though so

[1] Dingl., Pol. Jour., CLXXVIII, p. 43.
[2] Chem. News, Vol. 49, p. 3.
[3] Jour. Chem. Soc., 10, p. 234.
[4] Rose-Finkener, loc. cit.

far as concerns the conversion of the chloride and bromide to the iodide Siewert[1] shows it to be exact.

Maxwell-Lyte's method of proceeding, depending upon identically the same principle which Field attempts to utilize, consists in the solution of the silver haloid salts in potassium cyanide, the addition of potassium bromide, the decomposition of the potassium cyanide by means of sulphuric acid, with the consequent precipitation and weighing of the silver bromide mixed with the iodide of the original mixture — the resolution of this precipitate in potassium cyanide, the addition of potassium iodide, the decomposition of the cyanide as before with sulphuric acid, with the formation of a precipitate, which is presumably pure silver iodide and to be weighed as such.

To convert the chloride to the bromide Maxwell-Lyte uses a weight of potassium bromide equal to the weight of the silver chloride taken, and, to change the bromide to the iodide, a weight of potassium iodide one and a quarter times as great as the original weight of the silver chloride.

In the following experiments these amounts have varied widely, but the proportion of alkaline haloid salts employed is given for each case in the tabular statement.

The starting point was generally freshly precipitated silver chloride, but in the last three cases pure silver, this being dissolved in nitric acid, precipitated with potassium bromide (two equivalents), and the precipitate dissolved in potassium cyanide, converted to the iodide in the manner described, and weighed, the object of this being to test the convertibility of silver bromide to silver iodide.

In most cases the final precipitate after weighing was electrolyzed, so as to have a more perfect control upon the results of the conversion process, and at the same time to test the battery method additionally.

The bromide and iodide of silver were precipitated hot from dilute solutions, which were cooled and allowed to stand over night to settle before filtering.

Filtrations were made by the use of the Gooch crucible with gentle pressure. The silver salts were dried directly over a low Bunsen flame at a temperature far below the melting point, and dissolved, after weighing, by introducing crucible and asbestus into a strong solution of potassium cyanide and heating, the time necessary for the solution varying from a few minutes to several hours, according to circumstances. In some cases traces of reduced silver were found with the asbestus and were recovered by treating the felt with nitric acid and washing, the filtrate and washings being added to the main solution.

The deposition of silver was made in the platinum dish of 100 $cm.^3$ capacity, which held the solution, and the current found most suitable was (as Luckow originally ecommended)[2] developed by four Meidinger

[1] Zeitschr. anal. Chem., 7, p. 469. [2] Loc. cit.

ells of large size. With solutions of the volume named and the area of he negative electrode employed, it was found advisable not to attempt treat more than two grammes of the silver salt.

The solution was decanted immediately on the stopping of the curent, or, better, siphoned off while the battery connections were still nbroken, and washed with distilled water to prevent the solvent action f the cyanide on the deposit.

	AgCl taken.	AgBr found.	AgBr calculated.	Error.	Equivalents of K Br taken.
	grm.	grm.	grm.	grm.	
(6)	0.3260	0.4227	0.4270	0.0043 —	2
(7)	0.3093	0.4023	0.4052	0.0029 —	2
(8)	1.3801	1.8041	1.8080	0.0039 —	2
(9)	0.2091	0.2723	0.2739	0.0016 —	10
(10)	0.6846	0.8909	0.8968	0.0059 —	10
(11)	1.1625	1.5202	1.5230	0.0028 —	20
(12)	1.1734	1.5310	1.5372	0.0062 —	20
(13)	0.3501	0.4553	0.4586	0.0033 —	29
(14)	0.4178	0.5468	0.5473	0.0005 —	29

	AgCl taken.	Silver found.	Silver calculated.	Error.
	grm.	grm.	grm.	grm.
(6)	0.3260	0.2443	0.2453	0.0010 —
(7)	0.3093	......	......	......
(8)	1.3801	1.0385	1.0386	0.0001 —
(9)	0.2091	......	......	......
(10)	0.6846	0.5137	0.5152	0.0015 —
(11)	1.1625	......	......	......
(12)	1.1734	0.8829	0.8831	0.0002 —
(13)	0.3501	0.2634	0.2634	0.0000
(14)	0.4178	......	......	......

	AgCl taken.	AgI found.	AgI calculated.	Error.	Equivalents taken of K I.
	grm.	grm.	grm.	grm.	
(15)	0.6996	1.1451	1.1456	0.0005 —	2
(16)	0.7587	1.2429	1.2424	0.0005 +	2
(17)	0.6710	1.0992	1.0988	0.0004 +	10
(18)	0.2515	0.4118	0.4118	0.0000	10
(19)	0.6501	1.0646	1.0646	0.0000	10

	AgCl taken.	Silver found.	Silver calculated.	Error.
	grm.	grm.	grm.	grm.
(15)	0.6996	0.5255	0.5265	0.0010 —
(16)	0.7587	0.5691	0.5710	0.0019 —
(17)	0.6710	0.5042	0.5050	0.0008 —
(18)	0.2515	0.1892	0.1892	0.0000
(19)	0.6501	0.4892	0.4892	0.0000

	Silver taken.	AgI found.	AgI calculated.	Error.	Equivalent taken of K I.	Silver found.	Error.
	grm.	grm.	grm.	grm.			grm.
(20)	0.5418	1.1790	1.1789	0.0001 +	2	0.5417	0.0001 —
(21)	0.3750	0.8154	0.8159	0.0005 —	2	0.3746	0.0004 —
(22)	0.4078	0.8859	0.8873	0.0012 —	10	0.4077	0.0001 —

From these experiments it appears that the deposition of silver from the cyanide solution of the chloride, bromide, or iodide is exceptionally exact. The tendency of the process, however, is to yield low results, and yet, in spite of the multiplicity of operations through which the original material has been passed in the attempt to settle two questions at once, the deficiency is not very great, being 0.0005 grm. in the mean of eighteen determinations, with a maximum value of 0.0019 grm.

The conversion of silver chloride to silver bromide by the method proposed by Maxwell-Lyte, like its predecessor, is too imperfect to be worthy of trust, but the experiments indicate unmistakably that the change of silver chloride or silver bromide to silver iodide is sufficiently complete to afford the basis of a good analytical method.

The indirect estimation of chlorine and bromine, chlorine and iodine, or bromine and iodine in presence of one another may be effected satisfactorily, therefore, by precipitating both together as silver salts, filtering on asbestus, washing and drying at 150° C., weighing, dissolving the residue in potassium cyanide, and either electrolyzing the solution to determine the silver or precipitating the silver as iodide again, filtering upon asbestus, washing, drying, and weighing.

In a mixture of all three halogens the iodine is first to be separated by known methods, and the chlorine and bromine are to be indirectly estimated as described.

ON TWO NEW METEORIC IRONS AND AN IRON OF DOUBTFUL NATURE.

By R. B. Riggs.

THE GRAND RAPIDS METEORITE.

In the American Journal of Science (Vol. XXVIII, 3d ser., p. 297), Prof. J. R. Eastman called attention to an iron of probably meteoric origin, found near Grand Rapids, in Walker Township, Kent County, Michigan.

At the time a rough analysis was made on scanty material, identifying it as a true meteoric iron. Since then the iron has come into the keeping of the National Museum and a more careful analysis has been made, with the following results:

	Per cent.
Fe	88.71
Ni	10.69
Cu	.07
Mg	.02
P	.26
S	.03
C (combined)	.06
Graphite	.07
	99.91

The meteorite weighed originally about 52 kilograms. It is a compact mass of great apparent homogeneity, possessing a specific gravity of 7.87. One of the sections disclosed, however, a small nodule about one centimeter in diameter. This not being available for analysis, its composition remains undetermined.

Etched with nitric acid, the iron gives Widmanstättian figures very like those of the Robertson County meteorite, though of a finer character. No fracture lines were observed.

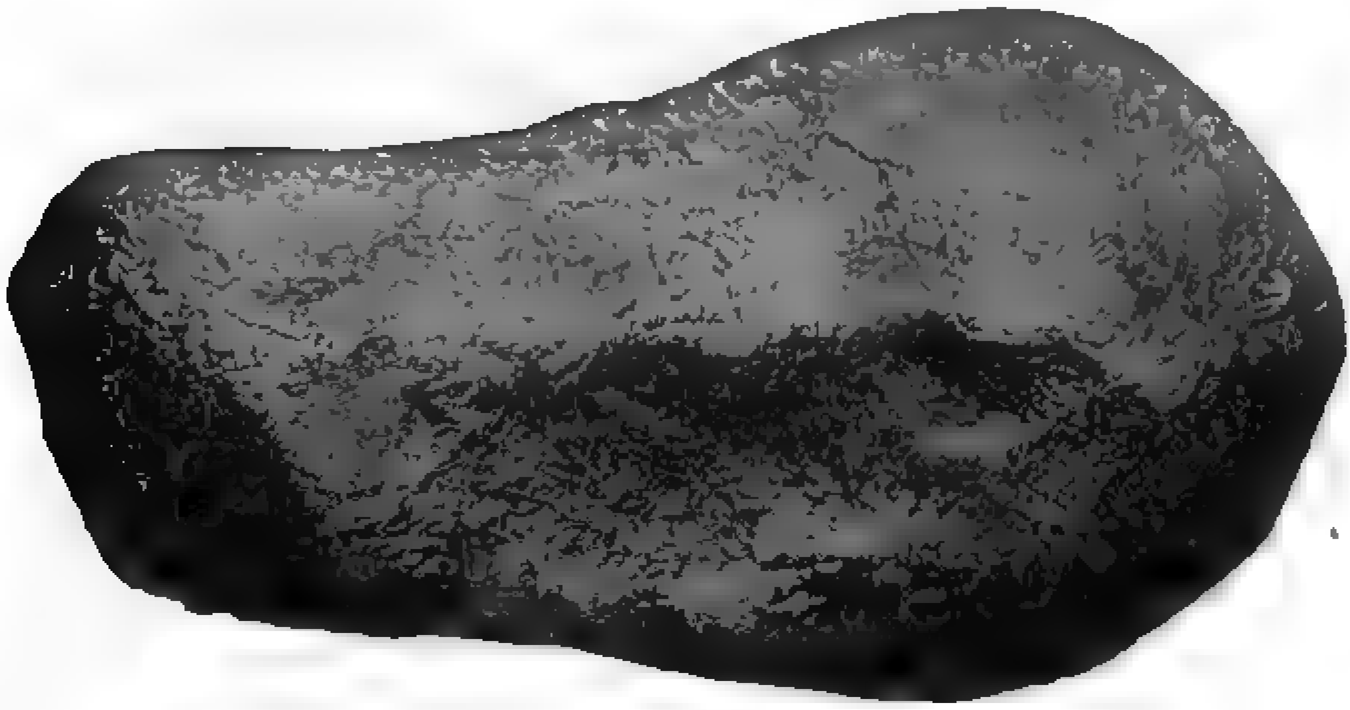

FIG. 4. Grand Rapids meteorite.

FIG. 5. Etched surface of Grand Rapids meteorite.

THE ABERT IRON.

This meteorite was found unlabeled in a collection of minerals made by the late Col. J. J. Abert, and was presented to the National Museum by his son, Mr. J. T. Abert. The iron, evidently not a fragment, weighed originally 456 grammes, and had a specific gravity of 7.89. A cross section measured 50 by 37 millimeters.

An analysis gave it the following composition:

	Per cent.
Fe	92.04
Ni	7.00
Co	0.68
P	0.08
S	0.01
C (combined)	0.02
Graphite	0.03
	99.86

Nitric acid brought out very characteristic Widmanstättian figures, of the same octahedral marking with, though somewhat coarser than, those of the Grand Rapids meteorite. The fracture is distinctly octahedral.

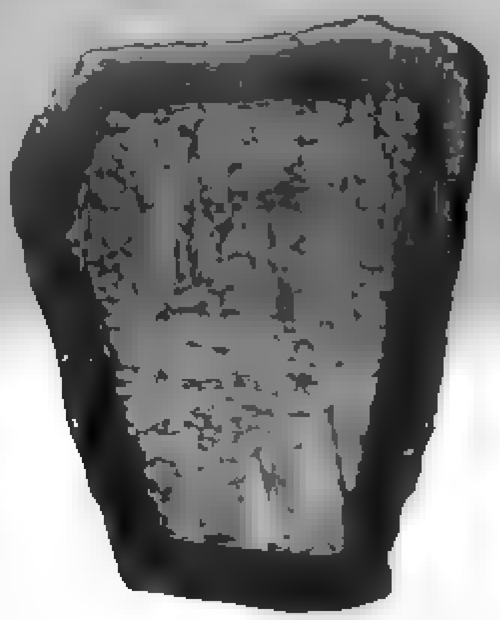

FIG. 6. Etched surface of Abert meteorite (actual size of section).

AN IRON OF DOUBTFUL NATURE.

This iron was found on the farm of A. L. Hodge, 3 miles southwest of New Market Station, Jefferson County, Tennessee. It is from a region full of small iron furnaces, whence have come a number of the pseudometeorites, among others the Hominy Creek, Rutherfordton, and Campbell County irons. Special inquiries were therefore made by Prof. Ira Sayles, who obtained the specimen, regarding the presence of furnaces in the vicinity. So far as could be learned, that locality was free from them. Full of cavities, the iron is characterized by great hardness, defying the use of saws. With a specific gravity of 7.61, it weighed 640 grammes. Fragments, however, had evidently been broken off from it.

The following are the results of an analysis:

	Per cent.
Fe	88.27
Ni	0.76
Co	0.19
Cu	0.03
As	Trace
Mn	6.73
Mg	0.14
P	1.80
Si	0.15
C (combined)	1.46
Graphite	0.86
	100.39

Treated with nitric acid, the polished surface developed quite fine markings not unlike Widmanstättian figures.

Its high percentage in manganese is possibly an objection (not by any means all sufficient) to ascribing to it a meteoric origin. The presence of manganese, and in considerable quantities, is not so uncommon as many think. The Claiborne and Bitburg meteorites, both of unquestioned origin, contain respectively 3.24 per cent. and 4 per cent. Furthermore, while the presence of nickel and cobalt proves nothing, so large an amount of phosphorus is not common in a furnace product.

THE EFFECT OF SUDDEN COOLING EXHIBITED BY GLASS AND BY STEEL, CONSIDERED BOTH PHYSICALLY AND CHEMICALLY.[1]

BY C. BARUS AND V. STROUHAL.

§ I. THE STRAIN IMPARTED BY SUDDEN COOLING, AND ITS RELATIONS TO TEMPERATURE.

INTRODUCTION.

In Bulletin 35 we communicated a series of results on the structure of steel of a given kind, tempered hard. They showed, in general, that from the circumference to the axis of a quenched, non-filable, steel cylinder hardness continually diminishes; that the first filable strata are encountered at a distance of about 1^{cm} below the surface. Moreover, as hardness decreases, the density of the elementary conaxial cylindrical shells increases, and in proportion as the layers become more and more nearly or easily filable the density is found to approach the density of soft steel. From an examination of rods of different diameters (2^{cm} to 3^{cm}) it appears, steel of a given kind presupposed, that the hardness at a point is essentially dependent on the distance of the point below the surface. The rate at which sudden cooling takes place must be similarly conditioned. Hence it is permissible to associate the one phenomenon with the other and to state that the hardness in a given point below the surface is dependent on the rate at which cooling there takes place. This point of view is suggestive; structure investigations may be made to furnish us the best means we know for the comparison of hardness and rate of cooling.

The results cited apparently make sad havoc with physical theories of temper. They seem indeed to be fatally at variance with the usually accepted views, viz: that in hard tempered steel an abnormally dense shell is arched around an abnormally rare core, the two states of strain mutually conditioning each other. The data may even be looked upon as furnishing evidence sufficient to prove the total absence of strain. It is the object of the present section to investigate in what measure this evidence is critically sufficient; if it be insufficient, to state the nature and relations of the strain effect of quenching somewhat more clearly than we were able to do in our earlier work.

[1] Our earlier work on the iron carburets will be found in Bulletins Nos. 14, 27, and 35.

In our little book on the iron carburets[1] we endeavored to contrast the respective merits of chemical and physical theories of temper, using for this purpose all the data known to us, as well as special results of our own. The deduction seemed warranted that hardness and strain are distinct and separate properties of a tempered iron carburet;[2] that they need not necessarily coexist. Leaving therefore hardness pure to be explained chemically, we inferred that the category of electrical and magnetic phenomena exhibited by steel on passing from hard to soft are mainly referable to changes in the character and intensity of the strain which the tempered rod carries. We accepted the theory of a dense shell and a rare core as being the most satisfactory and elegant conception of the strain in question, with the proviso[3] that "it must be regarded as a mere *diagram* of the essential features of the vastly more complicated structure of the glass-hard rod." These conditions premised, we finally interpreted all variation of strain produced by annealing as the combined effect of changes of the viscosity of steel due to temperature and of interference of thermal expansion with the said strain.

The experimental question which we are endeavoring to elucidate may therefore be succinctly put as follows:

(1) With what degree of sensitiveness do the variations of the density of the rod, as a whole, indicate the corresponding variations of strain?

(2) Is it possible successively to remove layer after layer of a rod without materially changing the character and intensity of the strain which the rod is supposed to carry?

(3) In how far does the actual structure of tempered steel differ from the diagrammatic distribution of density above assumed?

(4) Does the process of sudden cooling impart strain alike in kind[4] but differing enormously in degree to all substances?

In our paper on structure we had the second and third of these points principally in mind. We were unable to obtain direct and decisive evidence of the occurence of shrinkage during the removal of shells from a hard steel rod. But since the structure of steel differs so largely with the kind of steel operated upon, we do not regard our experiments as made in sufficient number to be conclusive. An examination of the density of the elementary shells shows that the character of the density at any point regarded as a function of the distance of a point below the surface is harmonic.[5] To investigate this relation it is unfortunately necessary to make the measurements for thin ($\frac{1}{2}^{\mathrm{mm}}$) shells. Hence the

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[1] Bull. U. S. Geol. Surv., No. 14, p. 76, 1885.

[2] Id., pp. 103, 127

[3] Bull. U. S. Geol. Surv., No. 14, pp. 95–98

[4] We do not necessarily refer to mere volume expansion here. See Wrightson, Jour. Iron and Steel Inst., II, p. 418, 1879.

[5] Bull. No. 35, U. S. Geol. Surv., p. 32, 1886.

mean amplitude of vibration and the limits of the unavoidable errors of observation are of the same order. To discriminate between the periodic effect of temper, which may show regular or irregular periodicity, and the apparently periodic distribution of mere errors of observation is difficult and requires very nice and careful observation. In Bulletin 35 we attempt to arrive at this discrimination by making minute comparisons of the structures of rods of the same kind of steel and of the same or of different diameters. This procedure is excessively laborious; it calls for a detailed construction of the relation of the density and the position of the points along any given radius of the rod and subsequent examination of the properties which the divers diagrams have in common. We have gathered many data, but the work is as yet incomplete, and the reader desiring further information will have to be referred to Bulletin 35, where the whole subject is discussed. Experiment on the fourth of the above topics we have now in progress and shall publish later. This narrows the purposes of this paper to the consideration of the first and most important of the above points, viz: In what degree the density of a hard steel rod at different points, even when measured with all attainable accuracy, is sufficiently sensitive to represent the character, relations, and intensity of the temper strain.

DENSITY AND RESISTANCE (STRAIN) OF TEMPERED STEEL.

Experimental results.—The discussion may be appropriately commenced by an examination of the variation of density of steel successively annealed from hard to soft. Our experiments on this subject, made in some number, are detailed in Bulletin No. 27, U. S. Geological Survey, and from this we select a digest of data sufficient for the construction of the following graphic comparison, a comparison which did not fall properly within the scope of the inquiry in Bulletin No. 27, and hence was there omitted. It is necessary to reiterate that the dimensions of the steel rods used were as follows:

TABLE I.

No	I.	II.	55 to 60 61 to 63	0.	36 to 36.
Average length of pieces (cm)	5.3	10.1	2.5	2.5	2.5
Number of pieces (cm)	1	1	21	19	72
Diameter (cm)	1.9	0.58	0.13	0.23	0.08

It was our constant endeavor to so anneal as to exclude all errors due to superficial oxidation and carburation. Whether this was accomplished remains to be seen. In Fig. 7 the temperature at which the rod was annealed is given as abscissa, the corresponding density as ordinate.

The commercial density for the respective cases is indicated by an attached *c*.

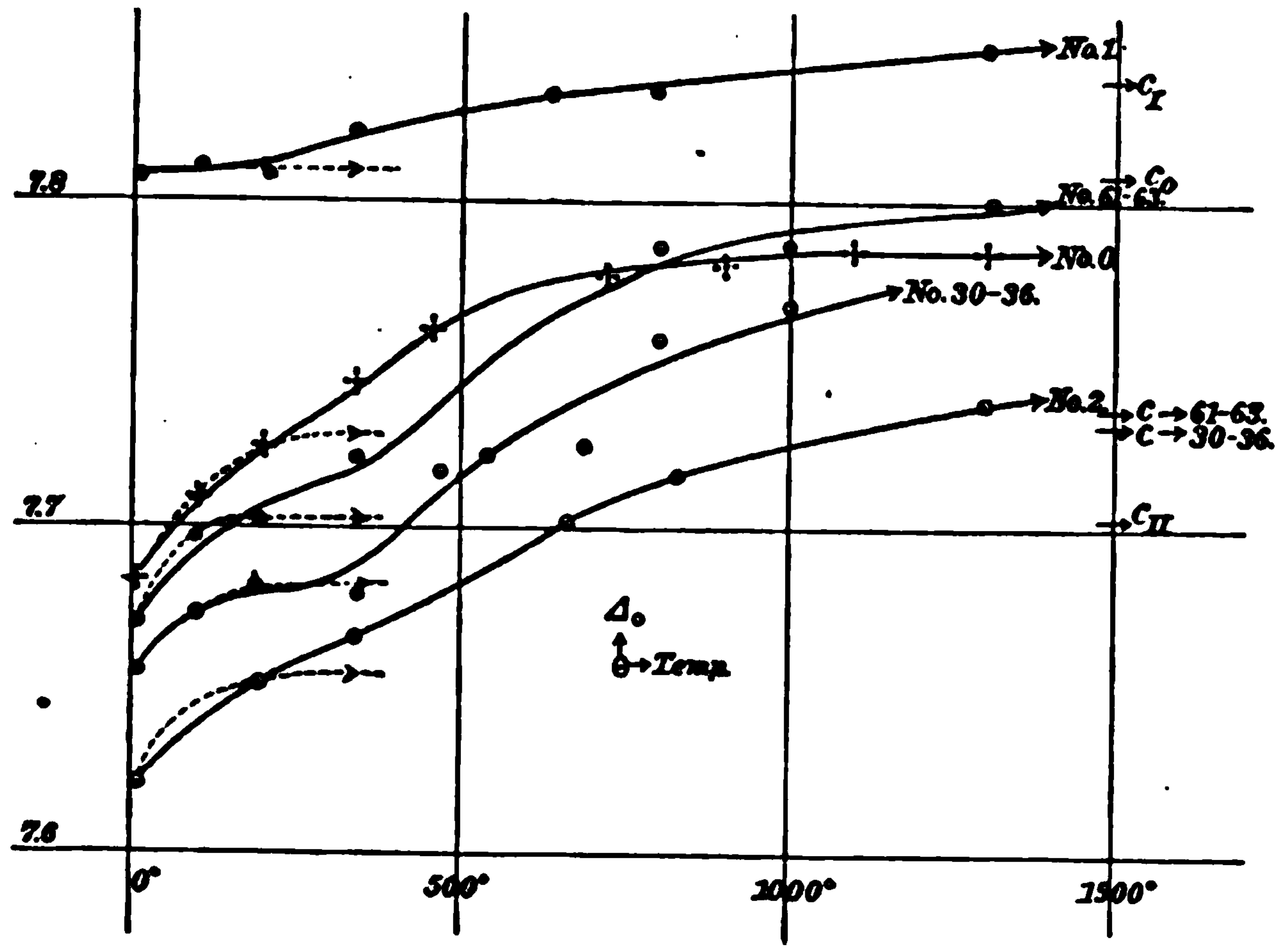

FIG. 7. Diagram showing variation of the density of steel, with temperature of annealing.

Discussion.—We advert in passing to the fact that, whereas density increases continually on passing from hard to soft, resistance passes through a pronounced minimum.

Whether we regard Δ_0 as a function of resistance or of the temperature t° at which the rod was annealed, the relations investigated lead to an important inference with an immediate bearing on our present purposes. It appears plainly that *the annealing of a rod successively from extreme hard to extreme soft does not exhibit the characteristics of a single and homogeneous phenomenon.* This annealing presents two distinct and independent phases, which merge into each other when t° corresponds to incipient redness. The graphic representation of Δ_0 varying with t° shows this transition with singular clearness. Between $t^\circ = 200$ and $t^\circ = 500$ all the loci pass through two consecutive circumflexures in such a way as to change the general and pretty uniform contours of concavity downwards into convexity downwards for the interval in question. The division of the complete phenomenon into two parts being thus suggested, we find on further inspection that the variations of the electrical constants of temper subside almost completely within the first of these parts (annealing between 0° and 350°); whereas in the second part (annealing between 350° and 1,000°) they become crowded and complex. It follows plausibly and at once that during the first of the phases under consideration we encounter the subsidence of a mechanical strain. This inference gains much in weight when we find that this strain vanishes, in the way peculiar to phenomena of viscosity, at a slowly decreasing rate, through infinite time.[1] In the sec-

[1] In other words, the temper strain vanishes just like the simple "drawn" strains imparted by the wire plate while the wires carrying them are each exposed to the prolonged action of temperature.—Bull. No. 14, U. S. Geol. Surv., p. 93.

ond phase, mechanical and chemical occurrences are superimposed and the above results do not enable us to disentangle them.

The final important deduction from the data is this, that during the first phase, in which the larger values of resistance are from two to three times the smaller values, the variation of density is slight. In the second phase we encounter large variations of density associated with small variations of resistance.

These curious relations characterize the phenomenon as a whole. We shall interpret them partially at least below.

DENSITY AND STRAINS IN TEMPERED GLASS.

Experimental results.—This result substantiates the evidence in favor of the existence of strain in hard steel adduced in our earlier papers.[1] Beyond this it shows almost conclusively that the density effect of the annealing of hard steel is out of all proportion and symmetry with the strain effect and the corresponding electrical effect. We were desirous, therefore, of studying the temper strain in substances other than steel and free from carbon. Long ago glass had suggested itself to us for this purpose.[2] We communicate in the following Table II the density effect produced by successive annealing of ordinary Prince Rupert drops. Twelve of these were in hand. Three were broken to test the strain, the remainder examined. All the drops contained included bubbles, one or more, often 0.2^{cm} to 0.3^{cm} in diameter and distributed irregularly. Usually a few large bubbles predominated. The drops moreover showed a purple coloration, which disappeared after annealing at incipient redness.[3] To anneal the drops at different temperatures we inclosed them in a test tube, cushioned upon and surrounded by carded asbestus. The end of the tube was submerged sufficiently to cover the Prince Rupert drops in boiling camphor, mercury, sulphur, &c., as given in the table. To anneal at red heat, the drops were suspended in little baskets of platinum foil, in the center of large thick clay crucibles, and then heated to the desired temperature in an assay furnace. Under all circumstances but one care was taken, to cool the drops slowly. Table II contains under "temper" the temperature and time of annealing, not including the time of cooling, however. The column m gives the weight of each drop in grammes. Variations of m are due to accidental breakage of the frail stems of the drops. Where no such breakage occurs m is constant. Δ_t is the density of the drops at $t°$; Δ_0, finally, is the density of the drops at 0° C., under the conditions given. Each Δ_0 is the mean of two independent determinations and is correct to within one or two units of the third place.

[1] Bull. No. 14, U. S. Geol. Surv., pp. 88–103.

[2] Wied. Ann., VII, p. 406, 1879.

[3] The color of the drops is amethystine. Mr. R. B. Riggs, of the U. S. Geological Survey, kindly analyzed the glass and found manganese.

TABLE II.—*Temper, weight, and density of quenched glass (Prince Rupert drops) successively annealed.*

No.	Temper.	m	t	Δ_t	Mean Δ_0	Remarks.
			°			
1	Quenched	1.3500	17.9	2.4336	2.4343	Bubbles; color.
		1.3501	17.0	2.4333	....	
	Annealed, 360°, 30^m (mercury)	1.3500	15.6	2.4388	2.4401	Do.
		1.3500	15.8	2.4894	....	
	Annealed, 600°, 10^m	1.3497	14.8	2.4894	2.4901	Bubbles and color vanish. Slow cooling; form of drop not changed.
		1.3496	15.3	2.4890	....	
	Annealed, red heat	1.3470	18.0	2.4901	2.4910	Slow cooling.
		1.3470	18.0	2.4896	....	
	Annealed, red heat	1.3311	18.4	2.4872	2.4883	Cooled in air.
	Annealed, red heat	1.3312	18.2	2.4904	2.4915	Cooled slowly.
2	Quenched	1.3200	17.5	2.4354	2.4364	Bubbles; color.
		1.3201	18.8	2.4354	....	
	Annealed, 360°, 30^m (mercury)	1.3201	15.7	2.4392	2.4408	Do.
		1.3200	15.8	2.4404	....	
	Annealed, 600°, 10^m	1.3191	15.1	2.4898	2.4903	Bubbles and color vanish; slow cooling; form of drop not changed.
		1.3190	15.5	2.4891	....	
	Annealed, red heat	1.3172	18.5	2.4901	2.4912	Slow cooling.
3	Quenched	1.4590	15.9	2.4364	2.4374	Bubbles; color.
		1.4590	16.0	2.4364	....	
	Annealed, 200°, 15^m (paraffine)	1.4591	15.9	2.4354	2.4364	Do.
	Annealed, 260°, 30^m	1.4590	16.5	2.4403	2.4411	Do.
		1.4590	16.9	2.4399	....	
4	Quenched	1.3305	16.0	2.4345	2.4356	Bubbles; color.
		1.3304	16.0	2.4348	....	
	Annealed, 200°, 15^m	1.3305	16.3	2.4341	2.4351	Do.
	Annealed, 380°, 30^m	1.3292	16.7	2.4369	2.4383	Do.
		1.3292	17.0	2.4378	....	
5	Quenched	1.3009	16.6	2.4333	2.4349	Do.
		1.3010	16.8	2.4344	....	
	Annealed, 200°, 1^h 30^m (camphor)	1.3009	15.9	2.4349	2.4359	Do.
	Annealed, 360°, 1^h (mercury)	1.3010	16.5	2.4390	2.4402	Do.
		1.3010	16.8	2.4394	....	
	Annealed, 450°, 30^m (sulphur)	1.3012	17.3	2.4441	2.4446	Do.
		1.3012	17.4	2.4431	....	
	Annealed, 550°, 10^m	1.2983	16.2	2.4521	2.4531	Color vanishes; slow cooling.
	Annealed, red heat	1.2982	17.5	2.4906	2.4914	Bubbles vanish; form of drop partially changed.
		1.2983	17.8	2.4900	....	
6	Quenched	1.4409	16.8	2.4312	2.4323	Bubbles, color.
		1.4408	16.9	2.4315	....	
	Annealed, 200°, 1^h 30^m (camphor)	1.4409	16.0	2.4323	2.4333	Do.
	Annealed, 260°, 1^h (mercury)	1.4409	16.7	2.4370	2.4382	Do.
		1.4409	16.9	2.4374	....	
	Annealed, 450°, 30^m (sulphur)	1.4412	17.1	2.4410	2.4422	Do.
		1.4412	17.4	2.4414	....	
	Annealed, 550°, 10^m	1.4410	16.4	2.4524	2.4534	Color vanishes; slow cooling.
	Annealed, red heat	1.4408	17.7	2.4878	2.4893	Bubbles gone; form of drop partially changed, slow cooling.
		1.4407	17.9	2.4885	....	
7	Quenched	1.4795	16.3	2.4385	2.4395	Bubbles; color.
		1.4795	17.6	2.4385	....	
8	Quenched	1.0024	16.3	2.4389	2.4395	Do.
		1.0026	17.6	2.4381	....	

TABLE II.—*Temper, weight, and density of quenched glass, &c.*—Continued.

No.	Temper.	m	t	Δ_t	Mean Δ_0	Remarks.
	Annealed, 360°, 30ᵐ (mercury)	1. 0025 1. 0025	17. 4° 17. 5	2. 4434 2. 4434	2. 4444	Bubbles; color.
	Annealed, 360°, 3ʰ (mercury)	1. 0023 1. 0023	16. 8 17. 2	2. 4474 2. 4471	2. 4482	Do.
	Annealed, 450°, 1ʰ (sulphur)	1. 0023 1. 0023	18. 2 16. 2	2. 4516 2. 4515	2. 4526	Do.
	Annealed, 450°, 4ʰ (sulphur)	1. 0023 1. 0023	16. 5 16. 8	2. 4570 2. 4574	2. 4586	Do.
	Annealed, red heat	0. 9982	18. 5	2. 4890	2. 4901	Bubbles and color gone; form partially changed, slow cooling.
9	Quenched	1. 2758 1. 2760	17. 0 17. 8	2. 4303 2. 4346	2. 4365	Bubbles; color.
	Annealed, 360°, 30ᵐ (mercury)	1. 2748 1. 2744	17. 4 17. 5	2. 4410 2. 4416	2. 4423	Do.
	Annealed, 360°, 3ʰ	1. 2745 1. 2745	17. 0 17. 4	2. 4425 2. 4427	2. 4436	Do.
	Annealed, 450°, 1ʰ	1. 2745 1. 2745	18. 2 18. 3	2. 4461 2. 4461	2. 4472	Do.
	Annealed, 450°, 4ʰ	1. 2727 1. 2727	16. 7 16. 9	2. 4499 2. 4501	2. 4510	Do.
	Annealed, red heat	1. 1592	18. 4	2. 4918	2. 4929	Bubbles and color gone; slow cooling, form of drop partially changed.

Table III, following, is constructed to facilitate a comparison of the important data. The second and third columns contain the densities of the extreme states of temper, the original quenched, "hard," and the final "soft," or thoroughly annealed state. The remaining columns contain the increments of density due to quenching, relative to the density of the soft state, the relative increments, in other words, which are retained at the divers temperatures given.

TABLE III.—*Summary showing density of Prince Rupert drops, quenched and annealed.*

No.	"Hard." Δ_0	"Soft." Δ_0	Density increment relative to "soft," when annealed at—						
			20°.	200°.	360°.	450°	(550°.)	(650°.)	Red heat.
1	2. 4345	2. 4915	−0. 0229	....	−0. 0207	....	....	−0. 0006	−0. 0002
2	2. 4364	2. 4912	−0. 0222	....	−0. 0202	....	....	−0. 0004	−0. 0000
3	2. 4374	....	−0. 0216	−0. 0220	−0. 0201	....	....	....	....
4	2. 4356	....	−0. 0223	−0. 0225	0. 0212	....	....	....	....
5	2. 4349	2. 4914	−0. 0227	−0. 0223	0. 0206	−0. 0188	−0. 0154	....	−0. 0001
6	2. 4323	2. 4893	−0. 0220	−0. 0226	0. 0205	−0. 0180	−0. 0144	....	+0. 0007
7	2. 4305	....	−0. 0207	....	....	....	....	....	....
8	2. 4395	2. 4901	−0. 0203	....	−0. 0184 −0. 0168	−0. 0150 −0. 0127	....	....	+0. 0004
9	2. 4365	2. 4929	−0. 0227	....	−0. 0203 −0. 0198	−0. 0184 −0. 0168	....	....	−0. 0007

Discussion.—The salient features of these data are obvious from an inspection of Table III. The density effect of quenching is decidedly *negative*, the increase of specific volume is exceptionally large. Moreover, the nine[1] Prince Rupert drops examined exhibit nearly the same initial density and nearly the same final density. The approximate equality of the values Δ_0 for the soft state is easily explained. It indicates that in proportion as we bring the strain to vanish we reach the normal density of the glass. It is not so easy to account for the observation that the density of the Prince Rupert drops shows almost the same degree of equality in the hard (quenched) state. Indeed, if we take the fact into consideration that the drops invariably contain *bubbles* distributed irregularly, and without apparent relation as regards size and number, the difficulties of explanation are increased. In other words, it is an exceedingly striking and important result that the volume increase due to quenching is quite as much the same for all drops as is at all possible for the case of so complicated an operation. We are thus led to this inference: Inasmuch as bubbles are present in like total volume in each of the drops, their presence cannot be a circumstance of mere accident; they must be regarded as a normal effect, or, better, a necessary result of the operation of quenching applied to glass; they must in some very intimate way be connected with the strain which the glass globules have experienced in virtue of sudden cooling.

Retaining this very reasonable surmise in mind, we proceed to a more minute inspection of the effect of annealing the hard Prince Rupert drops. We obtain results very similar to those investigated above for steel. The density effect of annealing is decidedly positive, and is greater as temperature and time of exposure are increased. Again, we readily divide the physical effect of annealing into two parts or phases. The first of these corresponds to the annealing temperatures 0° to 500°, the other to higher temperatures. The range of temperatures corresponding to the first phase is therefore larger for glass than for steel; and if we compare Tables I and II it appears obviously that for like density effects the annealing temperatures must be chosen higher in the former case (glass) than in the latter. But the change of density encountered in both instances is small; and yet, in spite of the small density effect during the inferior stage of annealing, by far the greater intensity of strain vanishes. The drops after annealing at 200° are still explosive; if they be broken after having been annealed in boiling sulphur at 450° they are found to have lost all traces of the explosive properties which the originally quenched drops possessed. Professor O. N. Rood[2] informed us that the polarization figures could be quite wiped out by annealing such ordinary glass as exhibited them only as far as the temperature of melting zinc. We infer that at the end of the first

[1] Further (incidental) examples are given in the next section, p. 115.

[2] Results obtained by Professor Rood during his experiments with high vacua.

phase of annealing we have in hand a hollow glass globule practically free from strain.

During the second phase of the annealing phenomenon (500° to 1000°), we observe a very pronounced change of the density of the Prince Rupert drops, corresponding to the above result for steel. But the explanation is here readily at hand; at incipient redness the inclosed bubbles *disappear* or are reduced to mere specks. The large increment of density in question is therefore nothing more than an expression for the collapse of the viscous hollow globule in virtue of atmospheric pressure. This important observation enables us to interpret all the phenomena of annealing satisfactorily. It must therefore be carefully examined.

We shall endeavor to prove that the bubbles are vacua, that they are not accidental inclusions of gas or aqueous vapor. The temperature from which glass is quenched is certainly less than 1500°. The temperature at which glass is sufficiently viscous to yield easily to atmospheric pressure is certainly greater than 500°. Suppose now that the changes of volume of the bubble were the result of thermal expansion of an included gas. Let v_{1500} and v_{500} be the volumes of the gaseous inclusion at 1500° and 500°, respectively, under normal pressure. Let v_h and v_s be the volumes of the gas bubble for the quenched (hard) and annealed (soft) states. Then we deduce, a fortiori,

$$\frac{v_h}{v_s} < \frac{v_{1500}}{v_{500}} = 2.3 \qquad (1)$$

With this as a point of departure the following little digest of mean results, Table IV, has been prepared. Here m is the mean mass of all the drops examined; Δ_h, Δ_s, V_h, V_s, their mean density and total volume for the hard and the soft states, respectively; v is the mean volume; r the equivalent mean radius of the bubbles. In the second horizontal row V_h has been diminished one-half per cent., to refer all volumes to the beginning and end of the second phase of annealing.

TABLE IV.—*Mean volume relations of the Prince Rupert drops and of the hypothetical gas bubble.*

V_h	V_s	v at—		r at—		
		1500°.	500°.	1500°.	500°.	
cc.	cc.	cc.	cc	c.	c.	
0.5454	0.5334	0.0120	0.0052	0.142	0.107	$\frac{v_h}{v_s} < 2.3$
0.5427	0.5334	0.0093	0.0041	0.130	0.099	$\frac{r_h}{r_s} < 1.3$

Mean $m = 1.3288$ g

"Hard:" Mean $\Delta_h = 2.4363 \pm 0.0008$

"Soft:" Mean $\Delta_s = 2.4911 \pm 0.0016$

Inasmuch as the values v_{500} and r_{500} are inferior limits, it is clear that, if the bubbles were gas or vapor, they would be of the same order of visibility before and after annealing. In other words, if the bubbles were gas, casual inspection would not detect a difference of their size in the "hard" (quenched) and in the "soft" drops. In the experiments, however, the bubbles all but vanish. Hence they cannot be gas.

To obtain additional assurance on this point we ground flat faces on the annealed drops Nos. 1, 5, and 8, and then measured the size of the inclusions. We found these values:

No. 1: $v_s = 0.000037^{cc}$.
No. 5: $v_s = 0.000062^{cc}$.
No. 8: $v_s = 0.000040^{cc}$.
Mean: $v_s = 0.000046^{cc}$.

From actual measurement therefore we find

$$\frac{v_h}{v_s} > 100 \tag{2}$$

a result wholly incompatible with $\frac{v_h}{v_s} < 2.4$, as derived above (Table IV). It follows conclusively that the bubbles are not accidental gas inclusions and that only an insignificant part of the variations of volume produced by quenching can be referred to thermal expansion of gas.

If the gas were aqueous vapor and if dissociation were complete, then the upper limit of (1) would have to be increased in the ratio of 3:2. This does not remove the discrepancy between (1) and (2). Moreover, since dissociation of water is only incipient at 1500°, and is not even complete at the temperature of melting platinum, the volume variation of the bubbles cannot be due to the presence of water in the bubbles.

If, on the other hand, we endeavor to explain the bubbles as vacuities[1] left by the contracting glass, we arrive at accordant and reasonable results. Let t be the temperature to which the homogenous glass drop must be heated in order that the observed mean volume of the soft state may be equal to the observed mean volume of the hard state. Then, since volume increases at an accelerated rate with temperature,

$$t < \frac{1}{3\alpha}\,\frac{\Delta_0 - \Delta_t}{\Delta_t} \tag{3}$$

where α is the ordinary coefficient of linear expansion of glass. By inserting the values of Table III into (3) we derive

$$t < 900°.$$

In other words, the quenched globule has retained the volume which the hot glass possessed at a temperature certainly smaller than 900°. This result taken together with the other is conclusive (see p. 112).

[1] Very analogous to Torricellian vacua.

The general result of our investigation on the process of sudden cooling, therefore, points out the fundamental importance of a rigid shell. As the material (glass or steel) cools, contraction as a whole takes place not centripetally but centrifugally, i. e., not towards the center of the figure, but away from it. So long as the interior remains liquid or viscous, the result is simple separation, commencing at points where minute air bubbles may pre-exist,[1] rather than at points of the continuity of glass. The final result is a vacuum bubble such as we have observed. In proportion as the interior becomes rigid the temper strain appears. Should the glass hold gases in solution, they would tend to escape into the vacua in question. There is probably another reason why in most instances the bubbles cannot be brought completely to vanish. Annealing reverses the whole phenomenon. The small changes of density observed in the first phase may be easily accounted for: it is probable that during these stages of annealing the rearrangement of molecules and disappearance of strain are accompanied by expansion inward toward the vacua. Hence the incommensurately small variation of mean density which accompanies the great optical effects (glass) and the great electrical effects (steel).[2] During the second stage of annealing, again, the density effect is incommensurately large; for glass it is the expression of a mere collapse, due to the atmospheric pressure. At all events the density effect (error) due to bubbles quite swallows up the density effect due to strain. Hence to represent the true relation of density and resistance or of density and annealing temperature in case of steel, it may be necessary to lower the part of the curves corresponding to the second phase of annealing by amounts equivalent to the bubble or fissure discrepancy, or else for like reasons to raise the parts of the curves corresponding to the first phase. If this be done, the circumflexures become less pronounced or disappear, and the points for the commercial soft state are more easily referred to the curves to which they belong. If, therefore, allowance be made for the distortion due to internal sensible pores, the relations become more uniform.

It is interesting to observe that glass retains the volume expansion corresponding to a temperature somewhat below 900°, whereas steel retains the volume expansion of a temperature below 400°. Similarly, the strain in steel is very perceptibly affected by annealing temperatures as low as 50°, whereas for glass the perceptible annealing effects are only incipient even at 200°. The amount of strain retained is, cæteris paribus, not merely a function of the viscosity of the material subjected to

[1] Prince Rupert drop No. 1, heated intensely in a blast lamp and cooled in air, shows a decrement of density. This is due to the rapid cooling; for when this drop is heated and cooled in the crucible, density is again incremented. The experiment shows the tendency of glass to retain strains. During the heating to 1000° no expansion of the very small bubbles was observable.

[2] The electrical and optical criteria may be considered equally sensitive.

quenching; it must depend also on the heat conductivity of this substance. For instance, if like figures of glass and of steel be quenched alike, then at the same time and depth the thermal gradient would be much steeper in the case of glass than in the case of steel. Hence, cæteris paribus, during quenching a rigid shell is possible in the case of glass for higher temperatures of the core than in the case of steel. The sudden contraction of the shell (pressure) has a marked effect on the melting point or degree of fluidity of the core. But it is best to waive this observation here, for the want of data to interpret it.

We have finally to consider the bearing of the results of this paper on the structure of steel. The detailed similarity observed in the annealing of glass and of steel suggests the inference that the interior of hard steel may be sensibly fissured. Under all circumstances the diagrammatic structure of dense shell and rare core would be inaccurate to the extent in which these fissures are irregularly distributed. Hence the difficulty of developing the true character of the dependence of the density (δ) at any point upon the distance of this point below the surface. We are able to account in part for the quasi-harmonic relations obtained both by Dr. Fromme[1] and by ourselves.[2] While the consecutive shells are being removed by solution, periodic fluctuation of δ must result whenever fissures are invaded. If, furthermore, we take into consideration that the density effect of even great intensities of temper strain is small, it appears that the true nature of the strained structure of tempered steel may be beyond the discernment of the density method of investigation altogether. The *gross* variation of density along the radius is a carburation phenomenon.

POLARISCOPIC OBSERVATIONS.

In this place we desire to substantiate the earlier inferences of this section and to give sharper expression to them. We therefore repeat Professor Rood's experiments on the polariscopic effect of continuous annealing of cooled glass at low temperatures. Our object is merely to detect variations in the polarization figure produced by annealing or, later in our work, by the removal of superficial shells. Hence it is sufficient to examine the drops in a given fixed position between polarizing plates.[3] Disturbances due to diffuse refraction are satisfactorily eliminable by submerging the Prince Rupert drop in glycerine, the refractive power of which is nearly that of the glass. The demarkation is then distinct and the colors clear, so that the figures can easily be drawn. The necessity of grinding special faces or plates is thus fortunately obviated, for in case of the quenched drop such operations are not feasible.

[1] Wied. Ann., VIII, p. 356, 1879.

[2] Bull. No. 35, U. S. Geol., Surv. p. 36.

[3] We are indebted to Professor Hitchcock for the use of a simple but efficient reflecting polariscope, formerly the property of Professor Joseph Henry.

In the case of simple annealing, variations of the polarization figure are due to a diminution of what we may loosely call the birefractive power of the Prince Rupert drop. In the case of removal of shells, as described in the next section, variations of figure result from diminution of thickness, possibly associated with diminution of birefractive power. The solution of the drop in hydrofluoric acid does not materially interfere with its transparency. The optic observations may therefore be continued indefinitely.

Our polariscopic experiments were made with the Prince Rupert drops Nos. 1, 2, 4, 6, and Nos. 3, 5, 7, 8, 9. The first four of these were simply annealed, the remainder[1] examined after consecutive removals of shells. It is expedient to describe only the experiments with annealed drops in this section. These experiments are so striking and so easily repeated, on the one hand, and so difficult to reproduce accurately in a drawing, on the other, that the following very careful free hand sketches of the main features of the figures are here inserted, principally for purposes of record. The cuts represent Prince Rupert drops Nos. 1, 2, 4, and 6 in fixed position between nicols.

On annealing as far as $T = 200°$, variations of figure are not certainly perceptible. After very long annealing at this temperature (200°) a faint influence appears, but is restricted to changes of color. It is particularly to be observed that the position and contours of the original polarization figure show a very obvious relation to the position of the included bubbles (black spots in the figure). This was the invariable result for all the Prince Rupert drops examined. It is in accord with our inference of "centrifugal" contraction,[2] discussed above. At 200°, therefore, change of strain in glass is incipient. The Prince Rupert drop, if broken, is still explosive, though perceptibly less so than the original drop.

After one hour of annealing in boiling mercury (360°) the changes of the polarization figure are obvious. The whole appearance is more diffuse, the colors bolder and broader, and the demarkation less distinct and delicate. These striking observations can only partially be reproduced in a figure. We have encountered very marked diminution of birefractive power. After seven hours of annealing in boiling mercury the evidences of diminished birefractive power have visibly increased. The figures as a whole are simpler, the coloration more gross.

Finally, after annealing in boiling sulphur (450°), the polarization figure has wholly vanished; we have in hand a hollow glass globule, free from æolotropic strain. We show on page 121 that the substance of the Prince Rupert drop is under a strain of dilatation. It is necessary to bear in mind that the isotropic part of this strain is not demonstrable by optic means. The drop annealed at 450°, however, has wholly lost its explosive character.

[1] § II, p. 116. [2] § I, p. 108.

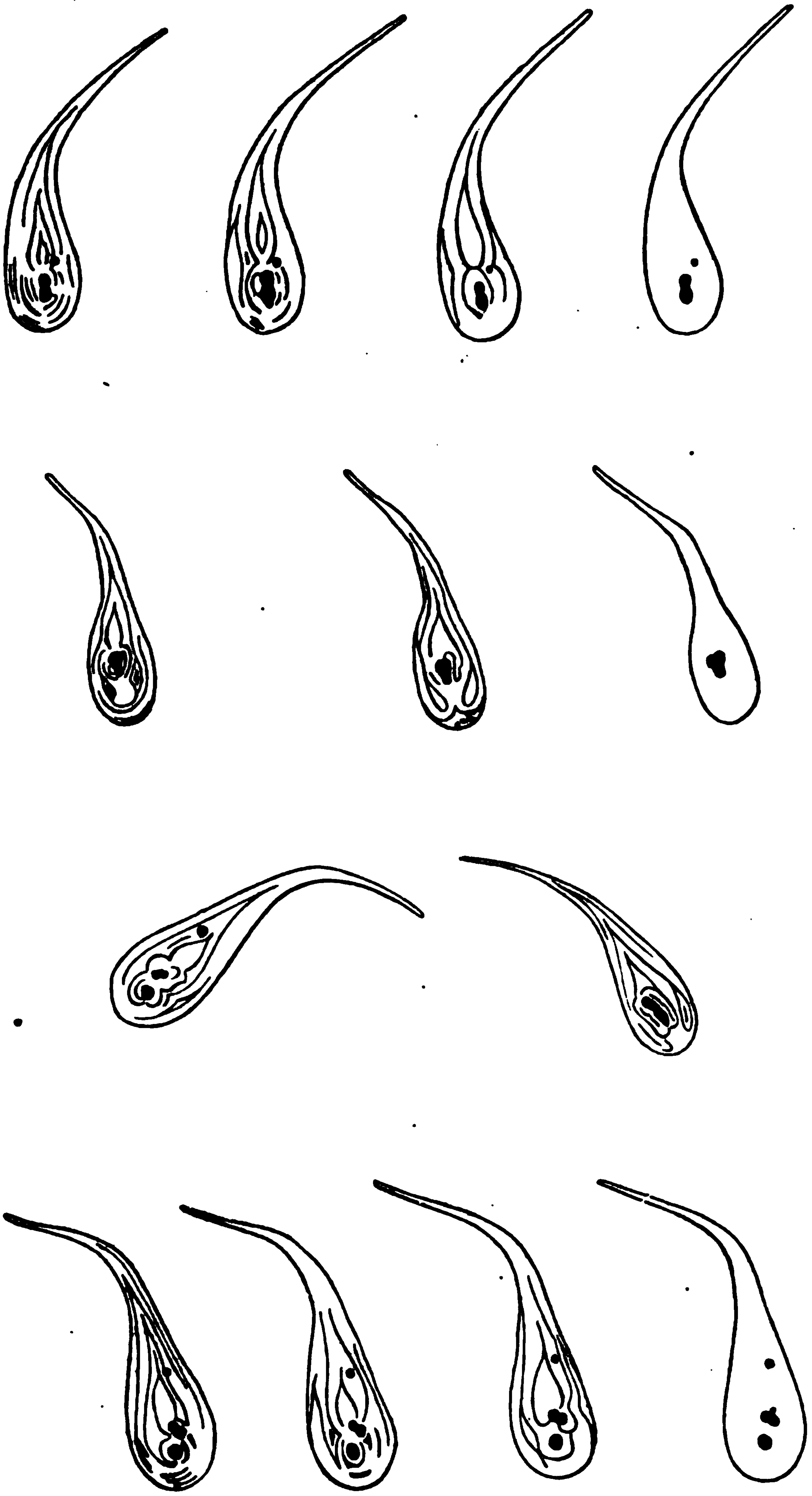

FIG. 8. Polarization figures of Prince Rupert drops.

Here we encounter the first important analogy between the optical behavior of quenched glass and the electrical behavior of quenched steel. We shall show that this parallelism extends even into details. Change of strain in glass is incipient at 200°, in steel at 50°. Change of æolotropic strain in glass is complete at a temperature certainly greater than 350° and less than 450°. The corresponding superior limit for steel cannot be so well defined. In both cases the essential dependence of the result to be reached on the temperature and the time of annealing (asymptotic relations) is the marked feature of the phenomenon.

§ II. THE STRAIN IMPARTED BY SUDDEN COOLING, AND ITS STRUCTURAL RELATIONS.

In the last section we compared the strains experienced by glass and by steel on sudden cooling by aid of the density variations observed on annealing the bodies carrying strain *as a whole*. Our purpose in this section is to investigate the density relations of consecutive similar shells of the Prince Rupert drop and the optical character of the successive cores. Availing ourselves of all the evidence adduced in our investigation at its present stage, we endeavor again to show that the optical effect of the temper strain in glass may be regarded as the precise analogon of the electrical effect of the temper strain in steel.

CERTAIN GENERAL PROPERTIES OF THE PRINCE RUPERT DROP.

It is well known that mere breakage of the tail of a Prince Rupert drop is sufficient to shatter it; the splinters fly apart with explosive violence. It is not so well known that the same drop may be dissolved in hydrofluoric acid to a mere spicule without exploding.[1] This peculiar behavior calls to mind certain properties of nitroglycerine, inasmuch as this substance may be burned off quietly in a wick but explodes on percussion. It is in keeping, moreover, with Dr. F. A. Gooch's ingenious suggestion that in the quenched globule we may possibly encounter a polymerization of the molecular structure of the annealed globule. But the fact that the strain is of an ordinary mechanical kind is proved by the observations of Table V, in which the behavior of Prince Rupert drops from which different thicknesses of shell have been removed by solution is described. In the table, "diameter" refers to the mean transverse thickness of the drops; ϑ and μ, to the thickness and the mass, respectively, of the dissolved shells. After removing a sufficient depth of shell, the residual explosive properties were tested either by crushing the reduced drop longitudinally in a vice or by striking in the same direction with a hammer.

[1] De Luynes appears to have been the first to dissolve the drop in HF (C. R. LXXVI, p. 346, 1873). He also discusses elaborately the effects produced by cutting glass with emery (C. R. LXXXI, 341, 1875). Some earlier work on the vacuum bubble is due to *Reusch* (*Phil. Mag.* (4), XXXIV, p. 166, 1867).

TABLE V.—*Explosive qualities of Prince Rupert drops.*

No.	Minutes in H.F.	Diameter.	ϑ	μ	Remarks.
		cm.	*cm.*	*g.*	
12	0	0.848	0.006	....	Shattered on breaking base of tail. Explosive tendency diminished in marked degree.
	5	0.835	....	....	
10	0	0.796	0.015	....	Shattered on being split longitudinally. Fragments partially cohere.
	10	0.766	....	....	
11	0	0.795	0.017	....	Shattered on being split longitudinally. Fragments partially cohere.
	14	0.760	....	....	
13	0	0.774	0.031	0.291	Shattered on being split longitudinally. Fragments more coherent.
	30	0.712	....	....	
3	0	0.795	0.054	0.493	Is not shattered on splitting. Conchoidal fracture.
	....	0.688	....	....	
5	0	0.825	0.053	0.491	Is not shattered on splitting. Conchoidal fracture.
	....	0.720	....	....	
7	0	0.763	0.112	0.723	Is not shattered on splitting. Conchoidal fracture.
	....	0.539	....	....	
8	0	0.791	0.117	0.752	Is not shattered on splitting. Conchoidal fracture.
	....	0.557	....	....	

The table shows that the explosive tendency of the Prince Rupert drop becomes rapidly less pronounced as the thickness of removed shell increases, that this tendency is very perceptibly impaired by the removal of less than $\frac{1}{10}^{mm}$ of shell, and that it vanishes almost wholly after the removal of $\frac{1}{2}^{mm}$ of shell. If the radius of the drop be diminished about 0.03^{cm} the particles of the fractured globule frequently cohere, and the original structure may then be inferred from the general direction and distribution of the fissures. The arrangement of the individual fragments is quite characteristic: they are found to be flat, irregular conoids, with their apices toward the line of symmetry of the drop, their bases in its surface—an arrangement something like the eye of an insect, or even more like the fruit cone of a spruce tree. In other words, the radial structure of the fissured Prince Rupert drop is very distinctly marked.[1] This proves that the original (unbroken) drop must have possessed a box-within-box structure; that, if the bubbles were symmetrically disposed, particles similarly situated with reference to the line of symmetry would be in like states of strain. But the law according to which matter is distributed from circumference to axis cannot be inferred, since the stated phenomena follow equally well both for surface dilatation and for surface compression.

All the Prince Rupert drops examined were found to scratch ordinary glass with facility; but, on removing the strain from the drops by annealing them at white heat and slowly cooling them, their hardness

[1]This structure is frequently visible in fragments of large tempered steel projectiles. I have found glass rods which on sudden heating break up into flat fragments symmetrically disposed around the axis of the rod or again into symmetric conoidal shells (see note on researches of De Luynes, on preceding page).

did not observably change. The hard quality was therefore a property of the glass itself and was not imparted by mechanical treatment. Indeed, on rubbing together a quenched and an annealed Prince Rupert drop no difference of hardness could be discerned.

GENERAL STRUCTURAL EFFECTS PRODUCED BY SUDDEN COOLING.

In Bulletin 35 we communicated a series of results on the resistance of consecutive conaxial layers of steel rods.

We there showed that it is difficult to arrive at accurate values for specific resistance in these measurements, for we encounter very small values of total resistance at the inception of the experiments and small and irregular values of sectional area at the close. Inasmuch as sections are necessarily measured too large, the values for specific resistance, S_0, are too large, and the error increases rapidly as we pass from greater to smaller diameters. The mean error of S_0 is certainly several per cent., and hence the resistances of elementary shells calculated from these data are only approximations. Nevertheless our results are important; they prove that in the case of hard rods less than 0.6^{cm} thick the values of resistance taken from circumference to axis along any radius do not perceptibly diminish. It was this curious result, apparently adverse to the hypothesis of strain, which induced us to examine the corresponding behavior of quenched glass.

The diameters, 2ρ, of Prince Rupert drops Nos. 3, 5, were successively reduced[1] as follows:

	$2\rho = 0.79$	0.75	0.72	0.69	0.62	0.56	cm.,
and	$2\rho = 0.82$	0.79	0.75	0.72	0.65	0.59	cm.

The polarization figures drawn after each of these reductions are subjoined.

The figures of each drop retained a uniform character throughout and showed no further loss of delicacy of demarkation and of colors than could be referred to diminished thickness. Unfortunately it is not easily possible to discriminate between the effect of decrement of diameter and the possibly concomitant effect of lessened birefractive power. Hence the experiments fail to indicate whether the removal of consecutive shells by solution is accompanied by changes of strain (shrinkage). If the fragments of a shattered drop, submerged in glycerine, be examined under the microscope between crossed nicols, the presence of strain in the individual splinters is quite clearly apparent. It is well to note that marked polariscopic evidence of strain remains long after the explosive properties of the Prince Rupert drops have disappeared. We infer that the electrical behavior (resistance) of the successive cores of a hard steel cylinder is not unexemplified by the optical behavior of successive cores of a Prince Rupert drop; though

[1] We desisted from further reduction of diameter in order not to enter the bubbles.

it is difficult to say whether the behavior of the partial bodies in either case (partial strains) is at all comparable with the behavior of the bodies as a whole (temper strain).

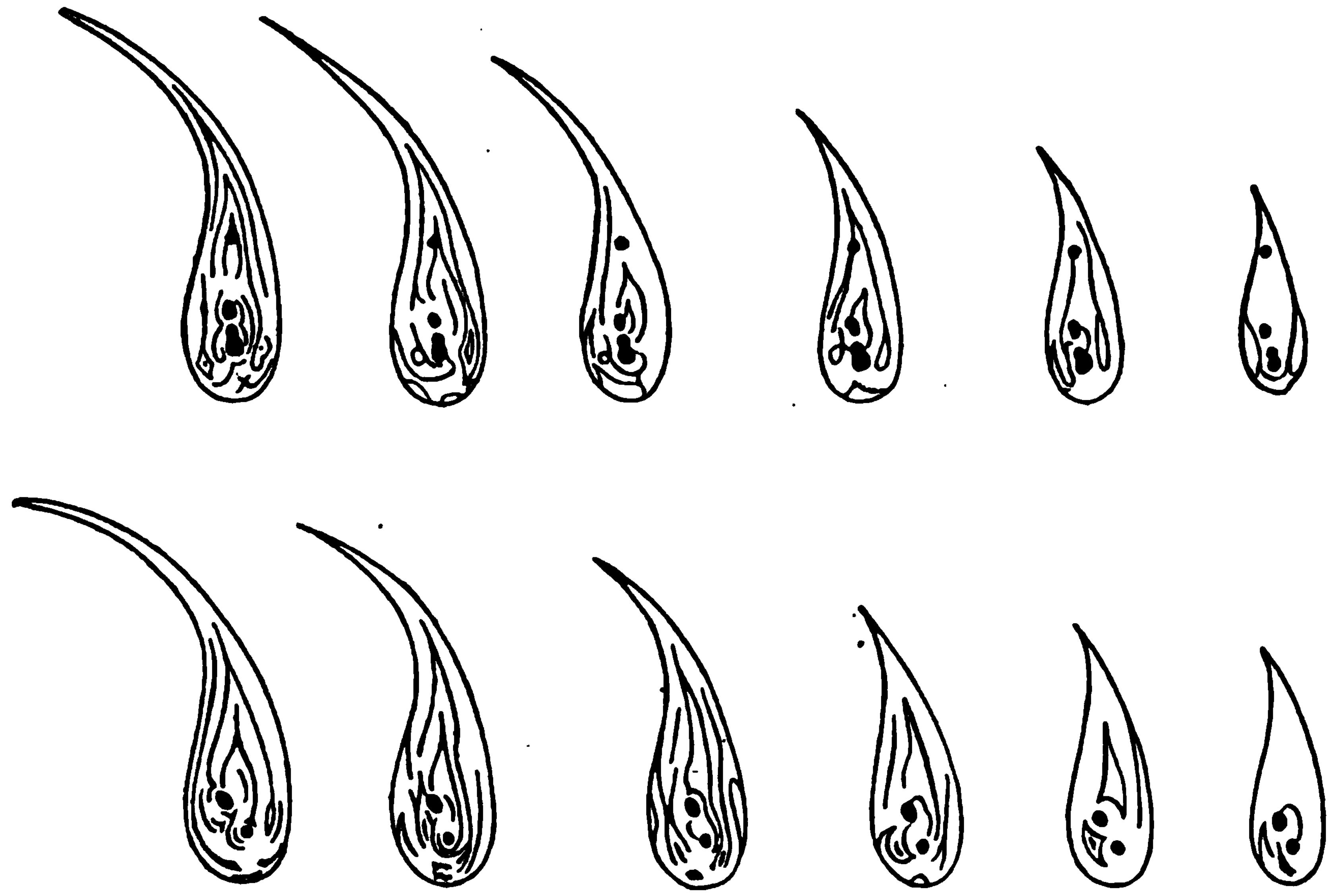

FIG. 9. Polarization figures of successive cores of Prince Rupert drops.

In this place it is well to advert to certain important data of Table IX. Having removed two shells (total thickness, $\vartheta_1+\vartheta_2 = 0.04^{cm}$) from each of the Prince Rupert drops Nos. 10 and 11, the core densities were found to be 2.4166 and 2.4147, respectively. We then annealed them in sulphur (450°), and found for the densities of the annealed cores 2.4263 and 2.4261, respectively. This increment is quite as large as is observed when the drops are annealed *as a whole*.[1] Hence we fail to appreciate any diminution of strain due to solution. Moreover, we prove conclusively that the increment of density which is observed on annealing at the said temperature (450°) is a true increment of the density of the substance of the Prince Rupert drop; that is, not a partial collapse of the drop in virtue of atmospheric pressure. In other words, the observed *after action* is inherent in the glass itself, as we pointed out elsewhere.[2]

DISTRIBUTION OF DENSITY IN PRINCE RUPERT DROPS.

Results.—Availing ourselves of the property of the Prince Rupert drop to dissolve quietly in hydrofluoric acid, we arrived at the following results (Tables VI to X) for the variations of density along transverse radii of the drops. In these tables "diameter" denotes the mean

[1] § I, p. 104. [2] § I, p. 108.

transverse thickness of the successive cores; M and Δ_t show their mass and their density at the temperature t; Δ_0, their mean density at 0°C. Furthermore, μ, ϑ, δ, R, denote the mass, thickness, density, and mean radius, respectively, of the consecutive shells. If the n^{th} core be left after the removal of n shells, then the suffixes to the number of the drop in the first column give the history of the drop succinctly. Nearly all the measurements are made independently in duplicate. Δ_0 may be relied upon to within two units of the third place; δ, to one unit of the second place. In no case was solution carried so far as to invade the main bubbles of the drops; the drops were chosen as nearly as possible free from small bubbles. The fusions were made in platinum baskets suspended in thick closed clay crucibles. This insured very slow cooling.

TABLE VI.—*Structure of Prince Rupert drops quenched.*

Number.	Diameter.	M	Δ_t	t	Mean Δ_0	μ	ϑ	δ	Mean δ	R
	cm.	*grm.*		°C.		*grm.*	*cm.*			*cm.*
8_0	0.701	1.2577	2.435	15.5	2.4355	......	......	......	......	......
	0.800	1.2576	2.434	16.0	......	......	......	......	......	......
8_1	0.759	1.0375	2.426	16.1	2.4266	0.2202	0.020	2.483	2.478	0.387
	0.766	1.0374	2.426	16.3	......	0.2202	......	2.473	......	......
8_2	0.730	0.8894	2.419	16.7	2.4210	0.1481	0.015	2.461	2.461	0.370
	0.720	0.8893	2.421	16.8	......	0.1481	......	2.461	......	......
8_3	0.698	0.7651	2.411	17.0	2.4120	0.1243	0.010	2.474	2.479	0.353
	0.677	0.7650	2.411	17.3	......	0.1243	......	2.483	......	......
5_0	0.809	1.3002	2.439	15.0	2.4400	......	......	......	......	......
	0.840	1.3000	2.439	15.8	......	......	......	......	......	......
5_1	0.762	1.0924	2.435	16.3	2.4347	0.2078	0.020	2.465	2.469	0.403
	0.810	1.0923	2.434	16.5		0.2077	......	2.472	......	......
5_2	0.779	0.9317	2.428	16.5	2.4282	0.1607	0.017	2.477	2.473	0.384
	0.725	0.9318	2.428	16.6	......	0.1605	......	2.470	......	......
5_3	0.703	0.8090	2.418	17.1	2.4181	0.1227	0.010	2.495	2.496	0.368
	0.718	0.8090	2.418	17.4	......	0.1228	......	2.498	......	......

TABLE VII.—*Structure of Prince Rupert drops quenched.*

Number.	Diameter.	M	Δ_t	t	Mean Δ_0	μ	ϑ	δ	Mean δ	R
	cm.	*grm.*		°C.		*grm.*	*cm.*			*cm.*
7_0	0.766	1.0897	2.437	17.3	2.4386	......	......	......	......	......
	0.760	1.0897	2.438	18.1	......	......	......	......	......	......
7_1	0.750	1.0035	2.434	18.3	2.4346	0.0862	0.008	2.476	2.485	0.377
	0.743	1.0036	2.433	18.8	......	0.0861	......	2.494	......	......
7_2	0.736	0.9254	2.431	18.6	2.4322	0.0781	0.008	2.468	2.462	0.368
	0.722	0.9254	2.431	18.7	......	0.0782	......	2.435	......	......
7_3	0.718	0.8409	2.428	18.3	2.4288	0.0755	0.008	2.468	2.470	0.360
	0.706	0.8500	2.428	18.9	......	0.0754	......	2.473	......	......
7_4	0.685	0.7363	2.420	19.2	2.4200	0.1136	0.017	2.480	2.482	0.347
	0.672	0.7364	2.419	20.0	......	0.1136	......	2.484	......	......

TABLE VII.—*Structure of Prince Rupert drops quenched*—Continued.

Number.	Diameter.	M	Δ_t	t	Mean Δ_0	μ	[illegible]	δ	Mean δ	R
	cm.	*grm.*		°C.		*grm.*	*cm.*			*cm.*
7_5	0.647	0.6146	2.410	20.0	2.4096	0.1215	0.018	2.475	2.478	0.329
	0.635	0.6146	2.408	20.2	....	0.1216	....	2.481	......	......
7_6	0.610	0.5136	2.393	19.5	2.3950	0.1012	0.019	2.497	2.489	0.311
	0.597	0.5136	2.394	20.3	....	0.1012	....	2.480	....	......
7_7	0.534	0.3672	2.363	20.2	2.3640	0.1464	0.032	2.477	2.476	0.285
	0.544	0.3672	2.363	20.6	......	0.1464	....	2.475	......	......
8_0	0.781	1.1422	2.439	17.5	2.4396	....	.....	.....	......	......
	0.800	1.1422	2.438	18.0	....	....	....	.....	....	......
8_1	0.766	1.0667	2.436	18.4	2.4372	0.0855	0.007	2.477	2.469	0.391
	0.783	1.0667	2.436	18.6	....	0.0855	......	2.461	....	......
8_2	0.765	0.9739	2.433	18.7	2.4344	0.0828	0.010	2.477	2.471	0.382
	0.745	0.9739	2.434	18.6	....	0.0828	....	2.465	....	......
8_3	0.745	0.9024	2.431	18.5	2.4317	0.0715	0.008	2.435	2.469	0.372
	0.730	0.9024	2.430	19.0	....	0.0715	....	2.483	....	......
8_4	0.713	0.7741	2.421	19.3	2.4225	0.1283	0.016	2.489	2.489	0.361
	0.698	0.7741	2.421	19.8	....	0.1283	....	2.489	....	......
8_5	0.675	0.6567	2.412	20.2	2.4129	0.1174	0.019	2.479	2.478	0.343
	0.659	0.6567	2.412	20.2	....	0.1174	....	2.476	....	......
8_6	0.623	0.5459	2.403	19.7	2.4042	0.1108	0.018	2.454	2.457	0.324
	0.636	0.5460	2.402	20.2	......	0.1107	......	2.460	....	......
8_7	0.565	0.3901	2.373	20.4	2.3743	0.1558	0.036	2.485	2.483	0.297
	0.550	0.3901	2.373	20.6	....	0.1559	......	2.480	....	......
9_0	0.761	1.0518	2.4377	17.6	2.4390	....	......	......	....	......
	0.767	1.0517	2.438	17.8	....	......	....	....	....	......
9_1	0.746	0.9638	2.436	18.5	2.4370	0.0880	0.007	2.455	2.460	0.375
	0.742	0.9638	2.436	18.8	......	0.0879	....	2.465	....	......
9_2	0.720	0.8689	2.432	18.8	2.4338	0.0949	0.010	2.475	2.467	0.366
	0.726	0.8689	2.433	18.5	....	0.0949	....	2.459	....	......
9_3	0.711	0.7981	2.429	18.6	2.4302	0.0708	0.008	2.466	2.473	0.357
	0.703	0.7981	2.429	18.8	.....	0.0708	....	2.483	......	......
9_4	0.683	0.6932	2.423	19.5	2.4228	0.1049	0.016	2.473	2.474	0.345
	0.667	0.6931	2.423	19.6	....	0.1050	....	2.474	......	......
9_5	0.628	0.5846	2.415	20.2	2.4161	0.1086	0.019	2.469	2.466	0.327
	0.644	0.5845	2.415	20.2	....	0.1086	....	2.463	....	......
9_6	0.613	0.4867	2.400	19.8	2.4064	0.0979	0.018	2.456	2.465	0.306
	0.585	0.4866	2.404	20.2	....	0.0979	....	2.473	....	......
9_7	0.548	0.3471	2.375	20.5	2.3765	0.1306	0.031	2.488	2.484	0.283
	0.524	0.3471	2.375	20.5	....	0.1305	....	2.481	......	......

The following densities were found for glass very slowly cooled from fusion:

No.	7_7	8_7	9_7
M	0.3102	0.3424	0.2779
Δ_0	2.495	2.498	2.501

Table VIII, constructed on the plan described for Tables VI and VII, contains results for the variation of density along the transverse axis of drops annealed in boiling sulphur at 450°. Polariscopic observation showed these drops to be free from strain.

TABLE VIII.—*Structure of Prince Rupert drops annealed at 450°.*

No.	Diameter.	M	Δ_t	t	Mean Δ_0	μ	ϑ	δ	Mean δ	R
	cm.	*grm.*		°C.		*grm.*	*cm.*			*cm.*
1_0	0.766	1.1063	2.439	19.0	2.4398	......	......	......	......	......
	0.768	1.1062	2.439	19.0	......	......	......	......	......	......
1_1	0.708	0.8897	2.424	17.0	2.4242	0.2766	0.028	2.489	2.491	0.369
	0.713	0.8897	2.423	17.4	......	0.2765	......	2.493	......	......
1_2	0.685	0.7859	2.414	17.4	2.4147	0.1038	0.011	2.502	2.503	0.350
	0.690	......	......	......	......	......	......	......	......	......
3_0	0.960	1.8913	2.441	19.0	2.4420	......	......	......	......	......
	0.984	1.8914	2.441	19.2	......	......	......	......	......	......
3_1	0.920	1.4791	2.429	17.4	2.4303	0.4123	0.029	2.488	2.484	0.451
	0.828	1.4790	2.430	17.4	......	0.4124	......	2.481	......	......
3_2	0.798	1.3118	2.422	17.4	2.4231	0.1673	0.021	2.484	2.484	0.426
	0.866	......	......	......	......	......	......	......	......	......
6_0	0.792	1.2048	2.446	19.0	2.4408	......	......	......	......	......
	0.797	1.2048	2.446	19.0	......	......	......	......	......	......
6_1	0.743	0.9329	2.434	17.2	2.4340	0.2719	0.027	2.487	2.488	0.394
	0.738	0.9320	2.434	17.4	......	0.2719	......	2.490	......	......
6_2	0.707	0.8436	2.4274	17.4	2.4284	0.0893	0.015	2.504	2.504	0.362
	0.712	......	......	......	......	......	......	......	......	......

In Table IX, finally, we give the results for the Prince Rupert drops Nos. 10 and 11. The first two shells were removed from the drops while in the original (quenched) state. Both were then annealed for two hours at 450° and a further removal of shell effected. The numbers referring to the annealed state are primed. In other respects the notation is that of the preceding tables.

TABLE IX.—*Structure of Prince Rupert drops.*

No.	Diameter.	M	Δ_t	t	Mean Δ_0	μ	ϑ	δ	R	Remarks.
	cm.	*g.*		°C		*g.*	*cm.*		*cm.*	
10_0	......	1.2984	2.4333	21.5	2.4346	......	......	......	......	Quenched.
	......	1.2985	2.4331	21.9	......	......	......	......	......	
10_1	0.775	1.0766	2.4260	22.0	2.4269	0.2218	(0.02)	2.471	(0.30)	
	0.747	1.0767	2.4250	22.2	......	0.2218	......	2.475	......	
10_2	0.735	0.9014	2.4147	21.3	2.4166	0.1732	0.022	2.487	0.370	
	0.699	0.9014	2.4160	21.5	......	0.1733	......	2.475	......	
$10'_2$	0.733	0.9014	2.4253	22.0	2.4263	......	......	......	......	Annealed at 450°, 2h.
	0.700	0.9014	2.4248	22.2	......	......	......	......	......	
$10'_3$	0.697	0.7425	2.4127	22.0	2.4136	0.1589	0.020	2.488	0.348	
	0.654	0.7425	2.4118	22.3	......	0.1589	......	2.488	......	
$10'_4$	0.656	0.6133	2.3958	22.4	2.3982	0.1292	0.020	2.498	0.328	
	0.617	0.6132	2.3978	21.5	......	0.1293	......	2.482	......	

TABLE IX.—*Structure of Prince Rupert drops.*—Continued.

No.	Diameter.	M	Δ_t	t	Mean Δ_0	μ	ϑ	δ	R	Remarks.
	cm.	*g.*		°*C.*		*g.*	*cm.*		*cm.*	
11_0	....	1.0470	2.4350	21.6	2.4357	....	....	....	....	Quenched.
	....	1.0457	2.4337	21.7	....	....	....	....	....	
11_1	0.730	0.8555	2.4271	22.0	2.4281	0.1915	(0.02)	2.473	(0.37)	
	0.707	0.8555	2.4263	22.2	....	0.1902	....	2.469	....	
11_2	0.690	0.7178	2.4138	21.5	2.4147	0.1382	0.020	2.500	0.350	
	0.670	0.7173	2.4131	21.6	....	0.1382	....	2.499	....	
$11'_2$	0.690	0.7172	2.4245	22.0	2.4261	....	....	....	....	Annealed at 450°, 2h.
	0.670	0.7173	2.4249	22.0	....	....	....	....	....	
$11'_3$	0.626	0.5825	2.4077	22.1	2.4086	0.1347	0.023	2.502	0.329	
	0.644	0.5825	2.4067	22.2	....	0.1348	....	2.508	....	
$11'_4$	0.603	0.4678	2.3894	22.5	2.3919	0.1147	0.023	2.487	0.306	
	0.578	0.4677	2.3917	21.6	....	0.1148	....	2.471	....	

Discussion.—An inspection of Tables VI and VII shows at once that Δ_0, the density of consecutive cores, continually decreases. This is easily accounted for, since the bubble error becomes relatively large as the mass (M) of the Prince Rupert drop decreases.

If we construct the density of consecutive shells (δ) as a function of their mean radius (R) and then compare the diagrams which obtain for the five Prince Rupert drops, Nos. 3, 5, 7, 8, 9, we find that the loci have no salient feature in common. Possibly an increase of δ as we approach the deeper layers may be discernible, but it is indistinct. Hence the true variation of δ from surface to axis of a Prince Rupert drop is here unrecognizably obscured by errors of observation. Indeed, we shall find below that the probable total variation of δ attributable to strain will not far exceed 0.5 per cent. The accuracy of δ is certainly not within this figure. Again, if we compare the contours of corresponding curves $\delta = f(R)$, in Table V for drops free from strain, with each other and with the contours belonging to Tables III and IV, we encounter fluctuations of the same kind in both cases. These errors include the inaccuracies of mere measurement (the mass of the drops is unfortunately small and the pycnometer methods are not easily applicable), as well as such discrepancies as result from the unavoidable invasion of small bubbles during solution.

If, however, we compare the *mean* values of δ for strained shells (Tables VI, VII, and IX) with the mean values of δ for shells free from strain (Tables VII and IX), we find the latter values (unstrained glass) always in excess of the former. In other words, although our results are insufficiently sharp to enable us to describe the exact nature of the temper strain in glass, they do permit us to classify it as a *strain of dilatation*, so far as we have observed, throughout the substance of the drop. This observation is of importance, and we have therefore drawn

up the following general tabular comparison, to supplement the special and direct comparison given in Table IX.

In Table X Δ_s is the density of the glass itself after thorough annealing at red heat, as found in our earlier section, page 117, the datum being the mean value for six drops; Δ'_s is the density of the glass after *fusion* in a platinum basket and very slow cooling. The additional increment of the density of the glass thus produced is to be noted. δ_h and δ' denote the densities of shells strained (quenched) and unstrained (annealed at 450°), respectively. The sixth column contains the relative value of decrement of density for each drop; the second column, finally, the number of shells whose average δ is the datum given.

TABLE X.—*Density relations of tempered glass relative to soft glass (mean results for shells).*

$\Delta_s = 2.491$			$\frac{\delta'-\Delta_s}{\Delta_s}=0$		
Prince Rupert drop No. —	Number of shells dissolved.	δ_h		Δ'_s	$\frac{\delta_h-\delta'}{\Delta_s}$
3	3	2.473 ± 0.006	....	....	0.0076
5	3	2.479 ± 0.008	....	....	0.0052
7	7	2.477 ± 0.003	....	2.495	0.0060
8	7	2.474 ± 0.004	....	2.498	0.0072
9	7	2.470 ± 0.003	....	2.501	0.0083
10	2+2	2.477 ± 0.008	2.489 ± 0.002	....	0.0064
11a	2+2	2.485 ± 0.029	2.492 ± 0.026	....	0.0028
1	2	....	2.497 ± 0.006	....	....
2	2	....	2.484 ± 0.000	....	....
6	2	....	2.496 ± 0.008		..
Mean	(1½)	2.476	2.492	2.498	0.0063

a In view of the large value of probable mean error of this measurement, we thought seriously of rejecting it but we were unable to find any error in the work, and hence the datum has been retained. Its effect is principally apparent in the ratio, which it depresses in a way adverse to our inferences.

To facilitate further comparison, we insert also the corresponding table for steel.[1] Here 2ρ are the diameters of the steel rods; Δ_h, Δ_s, Δ_c, their densities in the hard, the soft, and the commercial soft states, respectively. Δ', finally, denotes the *observed densities of steel* at the end of the first phase of annealing (350°), and therefore applies for rods free from æolotropic strain. The table gives us the following relative decrements of density: column first, the total decrement; columns second and third, the decrements corresponding to the first and second phases of annealing, respectively.

[1] See Bull. No. 27, U. S. Geol. Surv., p. 46.

TABLE XI.—*Density variations of tempered steel relative to soft steel.*

No.	2ρ	$-\frac{\Delta_h-\Delta_s}{\Delta_s}$	$-\frac{\Delta_h-\Delta'}{\Delta_s}$	$-\frac{\Delta'-\Delta_s}{\Delta^s}$
I	1.90	0.0048	0.0018	0.0029
II	0.58	0.0155	0.0060	0.0095
61 to 63....	0.13	0.0171	0.0068	0.0103
0..........	0.23	0.0133	0.0080	0.0058
21 to 29....	6.08	0.0150	0.0033	0.0116
Mean ...	......	0.0131	0.0052	0.0079

Tables X and XI show that both in the case of glass and of steel the mean strain effect of sudden cooling is *dilatation* throughout the mass of the quenched material,[1] that the mean amounts of dilatation for glass and for steel are of like order, and that the strain in glass exceeds that of steel. We find, in general, that the practically measurable value of density is not a satisfactorily sharp datum for discerning the primary causes of the electrical, the optic, and the magnetic variations of the substance quenched. These, therefore, will have to furnish nice descriptions of strain and interpret what we have called elsewhere the individuality of magnets.

In the above paragraphs we have pursued the analogy between the optical behavior of tempered glass and the electrical behavior of tempered steel into every detail of consideration which urged itself. We availed ourselves, moreover, of additional criteria given by the density relations of the whole or of similar parts of the bodies quenched. At every stage of our work we reached data alike in character both for steel and for glass. With these results we are further justified in maintaining that sudden cooling of steel is accompanied by a strain effect of a distinct and individual kind and of an intensity sufficient to account for the electrical properties of steel (thermo-electric and resistance constants) such as we have found them.

In one of the earlier paragraphs of the present paper we pointed out that in its divers relations to hardness steel is distinguished from glass. To further our investigation it will therefore next be necessary to inquire more specifically into the causes of hardness itself, and at the same time to endeavor to throw light on the mysterious transformations of carbon.

§ III. THE HYDRO-ELECTRIC EFFECT OF TEMPER.

Our original object in writing these papers was that of elucidating questions having reference to the carburation of steel, from a purely physical standpoint. The reasoning available to the physicist is, however, of an analogical kind, and therefore as dangerous as it is fascinating. Hence, in view of the time already spent, it seemed expedient to en-

[1] If "quenching" means sudden cooling, then if the solid quenched be massive and thick the deep layers cannot be quenched in virtue of their position.

deavor to cut more nearly down into the heart of the inquiry and to determine directly the carbon relations of steel as a function of the temperature (0° to 400°, 400° to 1000°) and of the time of annealing, and to do this with full reference to the physical occurrences observed in the first and second phases of the phenomenon. So far as we know, M. Caron[1] alone has occupied himself with similar work; but his researches, being largely restricted to the extreme states "hard" and "soft," are incomplete. The carburation effect of annealing at measured temperatures during stated times is quite unknown.

Glass hard steel rods about 0.1^{cm} in diameter and tempered uniformly in the way described elsewhere[2] were each broken into four nearly equal parts and four samples of hard steel identical in composition and temper were thus obtained. These samples were annealed at 20° (glass hard), 100° 4^h, 200° 1^h, 360° 1^h, 1000° 5^m, respectively. Having treated these with cold dilute hydrochloric acid, we found that the rods annealed at 20° and at 100° dissolved without perceptible residue to a clear liquid; those annealed at 200° left a trace of flocculent carbon. Rods annealed at 360° yielded flocculent carbon in considerable amount; rods annealed at 1000°, finally, a comparatively copious and heavy carbon precipitate. The residues were collected in a weighed Gooch crucible (asbestus filter), thoroughly washed in the usual way,[3] dried, weighed, ignited in oxygen, again weighed, and the loss of weight on ignition estimated as carbon. The results thus obtained are sufficient for the present purposes:

Annealed at	20°, ∞	100°, 4^h	200°, 1^h	360°, 1^h	1000°, 5^m
Uncombined (graphitic) carbon per gramme steel, c.	<0.0007	<0.0007	0.0009	0.0021	0.0047

In a second series of similar experiments we found—

Annealed at	20°, ∞	100°, 10^h	200°, 1^h	360°, 1^h	450°, 1^h	1000°, 30^m	Commercial (soft).
Uncombined (graphitic) carbon per gramme steel, c	0.0001	0.0005	0.0005	0.0014	0.0009	0.0033	0.0053

In general, c increases at an accelerated rate with temperature. The large datum for the commercial state, as compared with the smaller values of c for steel softened by mere heating to redness, is an interesting feature of these results. The importance of the time effect is also to be noted. Temperatures as low as 100°, when acting on hard steel for long intervals of time (10^h), produce perceptible precipitation of the carbon in steel.

[1] Caron: Comptes-rend., LVI, pp. 43, 211, 325, 1863.

[2] Bull. 14, U. S. Geol. Surv., p. 29, 1885; Bull. 27, U. S. Geol. Surv., p. 30, 1886.

[3] Using dilute HCl, hot water, solution KOH, alcohol, and ether. See Blair: Report of the Board on Testing Iron, &c., I, p. 248. Washington, 1881.

On closer inspection it appeared that steel annealed at 100° is, cæteris paribus, more easily soluble than glass hard steel; steel annealed at 200° more easily soluble than steel annealed at 100°, and steel annealed at 360° more easily soluble than steel annealed at 200°. In other words, the rate at which solution takes place in general increases as temper continually decreases. These curious results were substantiated by annealing one-half of short glass hard rods (ca. 5^{cm} in length) at red heat on dissolving in HCl, the diameter of the soft length is diminished more rapidly than the diameter of the hard length. The diminution is usually greatest near the middle of the rod, where hard and soft parts meet, showing probably that local galvanic action here produces a perceptible result. At the same time steel annealed for hardness at a temperature in low redness is probably more soluble than steel in any other state of temper, hard or soft. Examples are given in the next table.

If we define the rate of solution as the mass dissolved per unit of area per unit of time, then in case of two submerged cylinders, for which during the time t the radii are reduced from ρ_0 to ρ and from ρ_0 to ρ', respectively, the rates, cæteris paribus, will be to each other as corresponding values of the expression—

$$-\delta\int_{\rho_0}^{\rho}\frac{2\pi\rho d\rho}{2\pi\rho}, \text{ or as } \frac{\rho_0-\rho}{\rho_0-\rho'}$$

The following table contains some of the results obtained with rods in the hard (h) and the soft (s) states, respectively, dissolved in acid, HCl, under identical conditions. m refers to the middle parts of the rods, concerning which mention has already been made. These ratios are subject, of course, to large variations (1 to 20), depending on the method of annealing, &c. The table is a fair exhibit of average values. The rods are lettered A, B, C, D.

TABLE XII.—*Rates of solution of hard and soft steel.*

[Original diameter, $2\rho_0$ = 0.120^{cm}.]

	Diameter.				Rates.				
	A.	B.	C.	D.	A.	B.	C.	D.	Mean rate.
h......	0.111	0.111	0.110	0.110	1.0	1.0	1.0	1.0	1.0
m.....	0.101	0.100	0.099	0.100	1.7	1.7	1.8	1.6	1.7
s......	0.102	0.103	0.102	0.103	1.6	1.5	1.5	1.4	1.5
h......	0.101	0.100	0.100	0.090	1.0	1.0	1.0	1.0	1.0
m.....	0.080	0.084	0.083	0.081	1.7	1.6	1.6	1.7	1.6
s......	0.094	0.092	0.091	0.090	1.3	1.3	1.3	1.3	1.3
h......	0.069	0.071	0.073	0.072	1.0	1.0	1.0	1.0	1.0
m.....	0.045	0.045	0.043	0.044	1.4	1.5	1.6	1.5	1.5
s......	0.067	0.070	0.070	0.071	1.0	1.0	1.0	1.0	1.0

TABLE XII.—*Rates of solution of hard and soft steel*—Continued.

[Original diameter, $2\rho_0 = 0.120^{cm}$.]

	Diameter.				Rates.				
	A.	B.	C.	D.	A.	B.	C.	D.	Mean rate.
h	0.122	0.123	0.122	0.122	1.0	1.0	1.0	1.0	1.0
s	0.115	0.116	0.115	0.113	2.7	3.3	2.9	3.2	3.0
h	0.116	0.116	0.116	0.115	1.0	1.0	1.0	1.0	1.0
s	0.103	0.106	0.106	0.104	2.3	1.8	2.0	2.0	2.0
h	0.090	0.090	0.090	0.090	1.0	1.0	1.0	1.0	1.0
s	0.052	0.061	0.052	0.058	2.0	1.8	2.0	1.9	1.9
h	0.078	0.077	0.077	0.076	1.0	1.0	1.0	1.0	1.0
s	0.038	0.020	0.028	0.043	1.8	2.0	2.0	1.7	1.9

[Original diameter $2\rho_0 = 0.082^{cm}$.]

	A.	B.	C.	D.	A.	B.	C.	D.	Mean rate.
h	0.077	0.077	0.078	0.076	1.0	1.0	1.0	1.0	1.0
s	0.070	0.065	0.066	0.068	2.4	3.4	4.0	2.3	3.0
h	0.070	0.070	0.070	0.070	1.0	1.0	1.0	1.0	1.0
s	0.060	0.051	0.058	0.051	1.8	2.8	1.9	2.6	2.2
h	0.043	0.011	0.044	0.043	1.0	1.0	1.0	1.0	1.0
s	0.000	0.000	0.000	0.000	2.1	2.0	2.1	2.1	2.1

From these results we inferred that hard and tempered steel would probably be distinguishable hydro-electrically; that, for the first phase of the phenomena of annealing, at least, this distinction might be more delicate than the estimation of precipitated carbon. To test this inference we selected the rods Nos. 1 *to* 12, *quenched uniformly glass* hard by our method. These were then broken in the middle and the first half of each rod was left in the glass hard state. The other halves were annealed in pairs at 20°, 100°, 4^h, 185°, 360°, 450°, 1000°, respectively. In order to anneal these (long) rods uniformly, we used a special device by which they were drawn vertically upward through a zone of constant temperature by clock work. If h be the height of this zone and ρ the radius of the disk or drum revolving once an hour, then

$$t = \frac{h}{2\pi\rho}$$

is the time of annealing in hours. Again, if we make $h = 2\pi$, then the time of exposure in hours is the reciprocal of the radius of the disk in centimeters. The great advantage of this method of annealing is that it requires but a very *small* zone of constant temperature;[1] it is therefore applicable at all temperatures and almost invaluable for high temperature work (500° to 1500°), where zones of a definite constant temperature are not easily produced. In this way we obtained six *pairs* of hydro-electric couples, each of which consisted of glass hard steel and the same steel annealed at one of the temperatures specified. Our first results were investigated with a zero method, and showed clearly that

[1] $2\pi \times \pi\,(0.3)\ \mathrm{cm}^3$ or even a narrower cylindrical figure being sufficient.

annealed steel is hydro-electrically positive with reference to hard steel and that the electromotive force increases with the difference of temper. But in view of the large polarization discrepancies incident to these measurements, the electrometer is preferable to the zero instrument. The following results were obtained with Mascart's apparatus adjusted to indicate 0.001 volt accurately. The electrodes of the steel couple were immersed in a concentrated solution of pure zinc sulphate contained in a U tube, the two limbs of the tube receiving the two steel wires. We kept them scrupulously bright by repeated scouring with sand paper. In the tables we give the electromotive forces, e, of the divers couples of hard and tempered steel, as well as the probable mean error, δe, of each. The means of the two values of e for each temperature of annealing are given in the second horizontal row and fairly exhibit the hydro-electric effect of temper in question.

The following data are the mean results of four sets of measurements of five observations per set. The rods were scoured before beginning the first and the third of these sets.

	No.	$e \times 10^3$	$\delta e \times 10^3$	Mean $e \times 10^3$
Annealed at 20°	9	± 4	....	±0.009
	10	±13	....	
Annealed at 100°	1	+12	±4	+0.000
	2	− 2	±5	
Annealed at 190°	3	+19	±3	+0.020
	4	+20	±1	
Annealed at 360°	5	+36	±3	+0.035
	6	+34	±3	
Annealed at 450°	7	+35	±3	+0.037
	8	+40	±3	
Annealed at 1000°	11	+49	±4	+0.052
	12	+54	±4	

The following data are the mean results of four sets of five observations per set; rods scoured before commencing each set of measurements:

	No.	$e \times 10^3$	$\delta e \times 10^3$	Mean $e \times 10^3$
Annealed at 20°	9	± 5	....	±0.003
	10	± 2	....	
Annealed at 100°	1	+ 8	±3	+0.007
	2	+ 7	±1	
Annealed at 190°	3	+20	±3	+0.022
	4	+24	±2	
Annealed at 360°	5	+34	±5	+0.030
	6	+27	±1	
Annealed at 450°	7	+35	±2	+0.039
	8	+43	±2	
Annealed at 1000°	11	+51	±2	+0.058
	12	+65	±5	

The following data, finally, are the mean results of two sets of three observations per set; rods scoured before commencing each set of measurements:

	No.	$e \times 10^3$	$\delta e \times 10^3$	Mean $e \times 10^3$
Annealed at 20°	9	± 2	....	± 0.003
	10	± 4	....	
Annealed at 100°	1	+ 6	±2	+ 0.006
	2	+ 6	±1	
Annealed at 190°	3	+16	±3	+ 0.021
	4	+25	±1	
Annealed at 360°	5	+36	±2	+ 0.035
	6	+34	±1	
Annealed at 450°	7	+37	±2	+ 0.038
	8	+39	±2	
Annealed at 1,000°	11	+59	±6	+0.062
	12	+65	±8	

The electromotive forces here encountered are small. It is necessary to take extreme precautions against all sources of error; otherwise mere discrepancies of polarization will exceed the largest values of electromotive force (e) found. If the parts of the liquid in which the steel wires are immersed differ at all in composition we may look for a difference of potential at the surface of separation of those parts. The number of such surfaces in a solution of solid liquid or gas may be indefinite. Hence it appeared desirable to repeat the above experiments with distilled water in place of zinc sulphate, to exchange the limbs of the U tube twice for each series of measurements (commutation), and to submerge equal surfaces of steel electrode in all cases. The results follow:

	No.	$e \times 10^3$	$\delta e \times 10^3$	Mean $e \times 10^3$
Annealed at 0°	9	+ 18	....	+ 0.023
	10	+ 28	....	
Annealed at 100°	1	+ 12	± 5	+ 0.020
	2	+ 28	± 9	
Annealed at 190°	3	+ 33	± 7	+0.027
	4	+ 20	± 8	
Annealed at 360°	5	+ 93	±11	+0.089
	6	+ 85	± 6	
Annealed at 450°	7	+128	±15	+0.105
	8	+ 82	± 9	
Annealed at 1000°	11	+166	± 5	+0.185
	12	+205	± 3	

A few supplementary data are contained in the next table, where Nos. I and II are (+) iron /(—) steel couples, both metals in the soft state; No. III, a couple of nominally identical iron wires; Nos. IV and V, couples consisting of steel in the commercial, drawn state (+), and the

same steel softened by heating to redness (—). The couples are immersed in water.

I.	II.	III.	IV.	V.
$e \times 10^3$	$e \times 10^3$	$e \times 10^3$	$e \times 10^3$	$e \times 10^3$
$+26 \pm 3$	$+63 \pm 2$	± 20	-69 ± 5	-65 ± 12

The general results of these measurements are in accordance; the variations of potential, when taken as a whole, regular and decided. They show that *as hardness increases the hydro-electric position of steel moves continually in an electro-negative direction.* The electromotive forces encountered are larger for the electrolyte distilled water than for zinc sulphate. The total range of variation in the former case (water) may exceed 0.25 volt. For zinc sulphate it scarcely reaches one-third of this amount and decreases as the time of immersion increases. After the first immersion, moreover, the original electromotive force is not fully restored even by rubbing the electrodes.[1] When steel is immersed in water the effect of repeated scouring seemed to be an increase of electromotive force. But these and like annoyances, which make the study of polarization phenomena unsatisfactory, are too well known to need further comment here.

If we avail ourselves of the observations made above on the rate of solution of tempered steel, we may infer consistently with all the facts adduced that, since the tempered electrode is covered with hydrogen[2] at a greater rate than the hard electrode, the former must be positive with respect to the other; that the phenomena in hand are mere effects of polarization. In other words it is permissible to assume that the continuous variation of mechanical texture producible by annealing is the cause of corresponding variations of the rate at which hydrogen is deposited on the submerged metal; that the electromotive forces observed are expressions of this hydrogen polarization and bear no immediate relation to the electro-chemical character of the steel electrode.

On the other hand the dependence of the hydro-electric position of steel, cæteris paribus, on the amount of free carbon contained is sufficiently obvious to conflict with this view. To facilitate comparison we insert the following table. Here c denotes the number of grammes of free carbon per gramme of steel; e and e' show the difference of potential between steel tempered and steel hard when plunged in zinc sulphate and in water, respectively; Δ is the density, s the specific resistance, α the

[1] After long exposure of the wires to air the original electro motive force again appears.

[2] Hydrogen accumulates visibly on the + electrode when both are immersed in zinc sulphate.

resistance temperature coefficient, h the thermo-electric hardness of wires of the same kind of steel. α and h are obtained by calculation.

TABLE XIII.

[Diameter, $2\rho = 0.081$.]

Annealed from hard at—	c	e	Δ	s	α	h	e'
° 20 ∞	0.0001	0.000	7.6547	43.9	0.0017	18.1	0.000
100, 1ʰ	......	......	7.6666	39.3	0.0016	16.2	......
100, 13ʰ	0.0003	0.000	7.6745	35.5	0.0020	14.6	0.020
190, 4ʰ	......	......	7.6841	30.8	0.0023	12.7	......
190, 4ʰ, 30ᵐ	......	......	7.6808	27.1	0.0027	11.2	......
Do	0.0007	0.020	7.6848	27.1	0.0027	11.2	0.027
350	0.0017	0.033	7.6806	20.7	0.0033	8.5	0.069
450, 1ʰ	0.0009	0.038	7.7190	18.4	0.0036	7.6	0.105
530	......	......	7.7227	18.2	0.0036	7.5	......
690	......	......	7.7272	17.2	0.0038	7.1	......
810	......	......	7.7586	17.6	0.0037	......	......
1,000	0.0040	0.057	7.7705	18.6	0.0037	......	0.185
Commercial	0.0053	......	7.7208	16.3	0.0039	6.7	0.252

When steel of a given kind is operated upon, and total carbon therefore a fixed quantity, the variable c affords a comparatively convenient means for detecting the presence and amount of chemical change; but it is highly probable that a much clearer insight into the nature of the decomposition of carbide produced by annealing hard steel would be obtainable from a study of the character and quantity of the hydrocarbons[1] (gaseous liquid) volatilized during solution. They accumulate in copious amounts long before the precipitation of carbon is perceptible, or even when no appreciable precipitation occurs. If we regard c and e or e' correlated, then we have in hand an example of an exceedingly remarkable decomposition, which may be regarded as incipient in hard steel even at ordinary temperatures, which is a certainly perceptible occurrence after annealing at only 100°, and which becomes more and more definitely marked and distinct as the temperature and time of annealing increase. The anomalous character of this species of decomposition, when occurring in a rigid solid, we have already fully pointed out. To obtain further information it is essential that the variable c be investigated minutely. We remark that the critical difference between the thermo-electric (h) and the hydro-electric (e) behavior of steel is well shown by constructing h as a function of e'. This is done in figure 10, which also contains c in its relations to e'.

[1] The liquid and volatile constituents seem to increase in amount as the steel dissolved is harder.

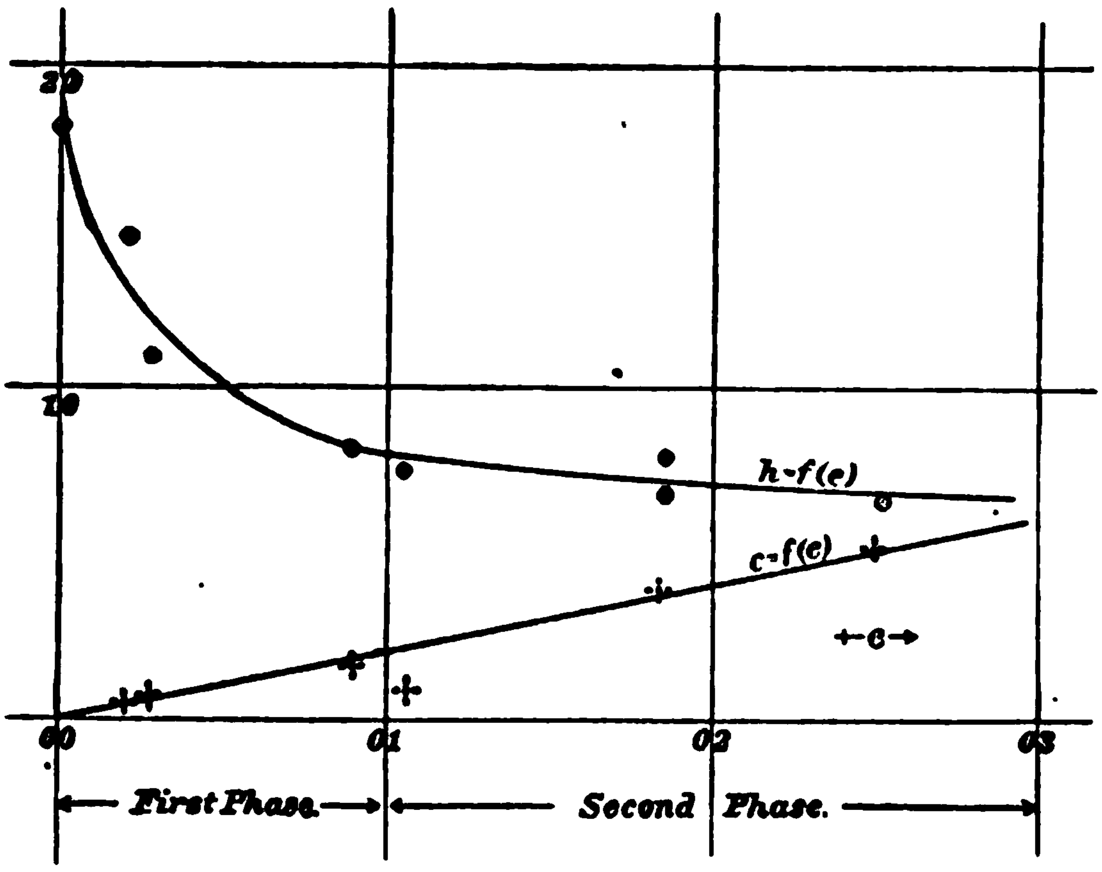

FIG. 10. Diagram illustrating the relation of graphitic carbon and thermo-electric hardness to the hydro-electric position of steel.

RETROSPECTIVE REMARKS.

The present results have materially substantiated our earlier views at every essential point. We may, nevertheless, further point out the presence and the importance of the strain effect by the following simple considerations:

The mass constants of the three types of cast iron, the extreme gray, the intermediate mottled, and the extreme white, range between the maximum density of 7.6 for white cast iron and the minimum density of 6.9 for gray cast iron. Density, therefore, *increases* in marked degree in proportion as total carbon is more and more nearly combined (from "gray" to "white"). Quite the reverse of this is true for steel, where density decidedly *decreases* as total carbon is more and more nearly combined (from soft to hard). This discrepancy is the temper strain, a strain of dilatation, which, in Chapters I and II, we carefully compare with the analogous behavior of glass. It is to be remembered that the given differences of density apply even to parts of the *same* cast of iron,[1] when these parts are respectively cooled rapidly (white) or slowly (gray).

With these general indications of the occurrence of stress, it is an important desideratum to obtain some estimate of its value. One method premises that the work done in mechanically expanding steel or glass from normal density to quenched density is equivalent to the work done by heat in effecting the same expansion. Here we have

$$\int p\, dv = A\, c\, T$$

where in one case unit of mass is acted on by a force p dynes per square centimeter during the volume increase dv cubic centimeters; where, in the other case, an identical total volume increment $(\int dv)$ is produced

[1] Karsten: Eisenhüttenkunde, Bd. I, 3. Aufl., p. 581 ff, 1841.

by an excess of temperature T degrees centigrade, applied to the same unit of mass and of mean specific heat c. A is Joule's equivalent. If, instead of variable p, we employ a mean constant value, P, and put for T the thermal value $\frac{1}{3\alpha}\int dv$,

We find

$$P = A\,\frac{c}{3\alpha}$$

Here

$$A = 42 \times 10^6,\ c = 0.2,\ 3\alpha = 25 \times 10^{-6}$$

hence we obtain

$$P = 320 \times 10^9$$

dynes per square centimeter, or circa 300,000 atmospheres. This is an absurdly large value and shows that in case of thermal expansion internal work is done which is not registered in mere volume increase.

We obtain very plausible stress values by introducing the elastic properties of glass or steel, probably because we are here relatively free from hypotheses. The compression (negative expansion) produced by quenching glass or steel is given in Tables X and XI, § II, and may be accepted as 5×10^{-3}. The volume resilience of glass and of steel, according to Professor Everett's[1] measurements, is 4×10^{11} and 2×10^{12}, respectively. Hence, if the force resisted in producing the volume increment of quenching be equivalent to the force producing the identical compression, we find $P = 10 \times 10^9$ dynes per square centimeter for steel and $P = 2 \times 10^9$ for glass. Now, the tenacity of steel is 8×10^9 per square centimeter; the tenacity of glass, 0.6×10^9 per square centimeter. The ratio of stress to tenacity is therefore 1.3 for steel and 3.3 for glass. This shows that in both cases stress and tenacity are of the same order, and that stress is in excess, and but for the peculiarly favorable and resisting arched structure of the quenched globule would give rise to rupture — in glass certainly, very probably also in steel. These results are estimates and are in accord with the observed explosive property of the Prince Rupert drop, and with the less pronounced tendency of steel to crack on quenching. We may infer, therefore, that quenched glass and quenched steel are under mean stress intensities of several thousand atmospheres; and in discussing the corresponding viscous properties of these substances they must be brought into relation with these high intensities of peculiar stress.

We call attention, in concluding, to the deductions of our earlier paper: "The annealing of steel, considered physically, is at once referable to the category of viscous phenomena. In the ordinary cases of viscosity measurements the phenomenon is evoked by sudden application of stress (torsion, flexure, tension, volume compression, &c.) under conditions of constant viscosity; in the case of annealing, by sudden de-

[1] Everett: Phil. Trans., p. 369, 1867. The above are round numbers.

crease of viscosity under conditions of initially constant stress. Thermal expansion interferes with the purity of these phenomena by destroying the conditions of existence of the strain which accompanies hardness, and this in proportion as the expansion is greater."[1]

Again, irrespective of the manifestation of mere hardness: "The existence of the characteristic strain in glass hard steel is the cause of electrical effects so enormous that such additional effects which any change of carburation may involve may be disregarded, and all electrical and magnetic results interpreted as due to variations in the intensity of the said strain."[2]

This deduction applies of course to the first phase of the phenomena of annealing, since it is within these limits that the strain in question is brought to vanish. With these results in hand we may proceed justifiably toward a study of the question whether the conditions for the permanent retention of magnetism in an iron carburet are not the identical conditions for the permanent retention of any strain. If we select the temper strain for comparison, we do it not merely because long experience has familiarized us with this strain, but because of the clear cut beauty of its manifestations and because of the simplicity of the functions which describe it.

WASHINGTON, *September*, 1886.

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[1] Bull. 14, U. S. Geol. Surv., p. 196. [2] Id., p. 197.

THE SPECIFIC GRAVITY OF LAMPBLACK.

By William Hallock.

The six samples of lampblack which formed the subject of this investigation were kindly furnished by Mr. Samuel Cabot, manufacturer of lampblack, in Boston, as samples of the different grades of commercial lampblack made by him. With the six samples came the following specifications with regard to the source or method of the manufacture of each:

I. Black from kerosene.
II. Black from coal tar naphtha.
III. Black from natural gas.
IV. Black from dead oil.[1]
V. Black from dead oil; very hot.[2]
VI. Black from dead oil; very light and fine.[3]

In order to get more nearly the pure lampblack, free from oil, &c., in each case, all the samples were washed in benzol, alcohol, and boiling water and dried at 180° C.

The following table will show the effects of the above washings; also, the percentage of ash, the original weight of the substance after standing fifteen hours in a desiccator being 100 per cent.

Number of sample.	I.	II	III.	IV.	V.	VI.
	Per cent	*Per cent.*	*Per cent*	*Per cent.*	*Per cent.*	*Per cent.*
Dried at 180° C	98.5	99.0				
Washed with alcohol and dried at 180° C	97.0	98.0	99.4	96.9	98.2	98.5
Washed with water at 100° and dried at 180° C	96.9	......	......	......	......	......
Washed with benzol and dried at 180° C	96.9	......	......	......	......	......
Ignited in O, ash	0.08	0.3	0.45	0.08	0.2	0.02

[1] This sample is from the back part of the receiving house, where small furnaces are used, and therefore the black is not highly heated.

[2] This sample is from houses where the furnaces are very large; therefore the black is exposed to a high degree of heat. It gives a large yield and is a cheap black.

[3] This sample is fine black from near the furnaces in the same receivers as IV.

The portions used for the determinations were washed in benzol, alcohol, and boiling water, dried at 180° C., and weighed after being in the balance case long enough to have a constant weight; of this point the particulars will be given later.

The specific gravity was determined by the pycnometer, using 10 per cent. alcohol as the liquid. The specific gravity of this was found to be 0.9864 at 20°.0C. In each case the sample was weighed dry in the pycnometer, then covered with 10 per cent. alcohol and put under the receiver of an air pump for several hours, until air was no longer given off. A test determination demonstrated that this did not appreciably alter the specific gravity of the liquid. After that the vessel was carefully filled, so as not to stir up the carbon settled on the bottom, the stopper put in, and the whole was weighed; then the stopper was removed and a small delicate thermometer was inserted into the liquid and the temperature noted. The pycnometer was then again closed, weighed, &c. Thus there were obtained three readings of the temperature and three weighings, the mean of which in each case served to calculate the specific gravity.

In this way the following values were found:

No. I.	1.7231 1.7233 1.7227	1.723	No. IV.	1.7668 1.7665 1.7670	1.767
No. II.	1.7797 1.7797 1.7803	1.780	No. V.	1.7890 1.7887 1.7881	1.789
No. III.	1.7513 1.7521 1.7521	1.752	No. VI.	1.7637 1.7636 1.7641	1.764

Too much reliance must not be placed upon these values, owing to the fact that the lampblack condenses on its surface a large amount of air, which is weighed with it when the weighing in air is made, but is absent when it is covered with the liquid. An idea of the extent to which this may affect the determinations may be obtained from the following statement.

A sample of No. II was taken after the washings and dryings, similar to that used for the specific gravity. The original weight is called 100 per cent.

Heated 2^h to 180°, then 24^h in H_2SO_4 desiccator	*a*	98.8
Heated 1^h to 180°, then 2^h in H_2SO_4 desiccator	*b*	98.7
5^h in balance case	*c*	100.55
Heated 3^h to 180°, then 40^m in H_2SO_4 desiccator	*d*	98.76
2 months in H_2SO_4 desiccator	*e*	99.2

Thus it appears probable the *dry carbon, free from air*, weighs only 98.75 per cent. (mean of *a*, *b*, *d*) of the weight as it comes from the sample tube

and as used above for the specific gravity. This, if it is general, would lower the above values of the specific gravity by about 1.25 per cent., or 0.022.

An attempt was also made to obtain some idea of the size of the grains of the black by the rate of sedimentation, on the principle that the finer the particles the slower the sedimentation. For example, a *single* particle falls through a liquid with a velocity proportional to the square of its diameter (radius).

For this purpose 0.1 gr. of each sample was taken from that used for the determination of the specific gravity and placed in test tubes about 20^{mm} by 120^{mm} dimensions. Upon each was poured 3^{cc} of alcohol, then ten shot, 2^{mm} in diameter, were put in each tube to help break up the black. After vigorous shaking 5^{cc} of water was added; then the tubes were heated till the liquid boiled, placed under the receiver of an air pump, and the pressure was reduced till they boiled there, when they were left 18^{h} to remove any air which might be condensed on the surface of the carbon. The tubes were then filled with distilled water well shaken and stood up to sedimentate.

After standing for the time given in the ninth column, Table I, two-thirds of the liquid was poured into another tube and that placed aside. The original tube was then refilled with distilled water, well shaken, and stood up until the next decantation, and so on, until the contents of the original tube would settle in a day or less. Thus each sample was separated into a series of lots of different fineness. The time required by these decanted lots to settle is given in Table II.

Unfortunately these results cannot be expressed in a very clear way, but in general the following is true:

Sample I. Settles quite completely in fifteen minutes, and hence is coarse.

Sample II. Settles in one day, and is hence much finer than I and III, but not so fine as IV, V, or VI.

Sample III. Same as sample I.

Sample IV. A little finer and slower than No. II.

Sample V and VI. These two are very nearly alike and are both *much* finer than any of the rest. Sample VI is, however, decidedly the finer of the two.

Of course any sample may behave as if it were coarse when each grain is, in fact, an agglomeration of several. This is hardly likely in the the above samples, since, if such were the case, we would be apt to find some fine black even in samples I and III.

I am fully aware of the incomplete and primitive character of this investigation, and sincerely hope it may incite some one with plenty of time and energy to take up the subject thoroughly and either confirm or refute my conclusions.

TABLE I.

Number of decantation.	Time of decantation.	Sample I.	Sample II.	Sample III.	Sample IV.
1	May 28, 1886, 11.45 a. m.	Clear after 15 m.	Opaque	Clear after 15 m.	Opaque.
2	12.2 p. m........	Discontinued ...	....do	Discontinued ...	Do.
3	2................	....	Translucent	....	Do.
4	3. 25............	....	....do	....	Dimly translucent.
5	3. 55............	....	....do	....	Do.
6	May 29, 1886, 11 a. m.	....	Very translucent.	....	Medium translucent.
7	12. 30 p. m	....	Discontinued ...	....	Medium translucent; settles now in a few hours.

Number of decantation.	Time of decantation.	Sample V.	Sample VI.	Interval between decantations or shaking.	Total time since commenced.
1	May 28, 1886, 11.45 a. m.	Opaque	Opaque	1 h. 55 m...........	1 h. 55 m.
2	12. 2 p. m........	....do	....do	17 m.............	2 h. 12 m.
3	2................	....do	....do	1 h. 58 m..........	4 h. 10 m.
4	3. 25............	....do	....do	1 h. 25 m.........	5 h. 35 m.
5	3. 55............	....do	....do	30 m.............	6 h. 5 m.
6	May 29, 1886, 11 a. m.	Very weakly translucent.	....do	1 h. 30 m.........	7 h. 35 m.
7	12. 30 p. m.......	Very weakly translucent; settles now in a few hours.	Opaque; settles now in a day or so.	1 h. 30 m..........	9 h. 5 m.

TABLE II.

Decantation.	Sample I.	Sample II.	Sample III.	Sample IV.	Sample V.	Sample VI.
1.............	Less than 1 hour.	Less than 1 hour.	Less than 1 hour.	Less than 5 days.	Not in 20 days.	Not in 30 days.
2.............	....	....do	....	....do	Translucent in 5 days.	Do.
3	....	....do		....do	....do	Translucent in 20 days.
4.............	....	....	....	1 day	Clear in 5 days.	Translucent in 5 days.
5.............	....	....	....	Less than 1 hour.	Clear in 1 day.	Do.
6.............	....	....	....	....do	....do	Do.
7.	....	....	....	....do	....do	Translucent in 1 day.

MISCELLANEOUS ANALYSES.

THE PERIDOTITE OF ELLIOTT COUNTY, KENTUCKY.[1]

[Specimens collected by J. S. Diller and analyzed by T. M. Chatard.]

A. Peridotite.
B. Olivine from peridotite.
C. Pyrope from peridotite.
D. Ilmenite from peridotite.
E. Syenite inclusion.
F. Slaty inclusion.
G. Calcareous sandstone near peridotite dike.
H. Indurated shale near peridotite dike.
I. Fine grained, fissile sandstone near dike.

	A.	B.	C.	D.
H_2O at 110°	8.92	.14	.17	.20
H_2O at red heat	......	.66		
CO_2	6.66	......	......	......
SiO_2	29.81	40.05	41.32	.76
TiO_2	2.20	.07	.16	49.32
P_2O_5	.35	.04	None	Trace
Cr_2O_3	.43	.24	.91	.74
Al_2O_3	2.01	.39	21.21	2.84
Fe_2O_3	5.16	2.36	4.21	9.13
FeO	4.35	7.14	7.93	27.81
MnO	.23	.20	.34	.20
CoO	......	Trace	......	......
NiO	.05	......	......	......
CaO	7.69	1.16	4.94	.23
MgO	32.41	46.68	19.32	8.68
K_2O	.20	.21	.07	.19
Na_2O	.11	.08		
SO_3	.28	......	......	......
	100.86	99.42	100.58	100.10

[1]Discussed by J. S. Diller in Am. Jour. Sci., August, 1886.

	E.	F.	G.	H.	I.
H_2O at 110°	.51	1.40	.85	......	1.94
H_2O at red heat		9.00	2.32	8.78	5.17
CO_2	......	.88	6.29	.55	....
SiO_2	60.56	35.53	60.78	41.32	60.25
TiO_2	1.19	.95	.03	.48	.23
P_2O_5	.30	.08	.09	.08	.10
Cr_2O_3	......	......	......	Trace	....
Al_2O_3	16.19	18.23	10.54	20.71	20.18
Fe_2O_3	5.19	2.46	3.27	2.59	1.53
FeO	2.41	4.81	......	5.46	3.42
MnO	.36	.13	.10	.17	.10
CaO	2.09	21.17	10.15	9.91	.51
MgO	1.30	2.01	1.59	1.91	3.52
K_2O	4.82	1.08	2.36	.88	3.17
Na_2O	4.78	2.53	1.41	7.19	.39
	99.70	100.26	99.78	100.03	100.51

TRENTON LIMESTONE FROM LEXINGTON, VA.

[Collected by H. D. Campbell. Analyses by R. B. Riggs.]

A. Limestone.
B. Residual deposit from subaërial decay of limestone.

	A.	B.
Ignition	1.08	12.98
CO_2	42.72	......
SiO_2	.44	43.07
Al_2O_3	......	25.07
Fe_2O_3	.42	15.16
CaO	54.77	.63
MgO	Trace	.03
K_2O	......	2.50
Na_2O	......	1.20
	99.43	100.64

RESIDUAL DEPOSIT FROM SUBAËRIAL DECAY OF CHLORITIC SCHIST FROM EIGHT MILES WEST OF CARY, N. C.

[Collected by I. C. Russell. Analysis by R. B. Riggs.]

SiO_2	54.54
Al_2O_3	26.43
Fe_2O_3	9.04
Ignition	9.87
	99.88

YELLOWISH BROWN, KAOLINIZED, DECOMPOSED TRAP FROM FOUR MILES WEST OF SANFORD, N. C.

[Collected by I. C. Russell. Analysis by T. M. Chatard.]

Ignition	13.26
SiO_2	39.55
Al_2O_3	28.76
TiO_2	.64
P_2O_5	.10
Fe_2O_3	16.80
Cr_2O_3	Trace
MnO	Trace
CaO	.37
MgO	.59
Alkali	Undet.
	100.07

ALTERED FELDSPAR FROM LAUREL CREEK, GA.

[Analysis by T. M. Chatard.]

H_2O	8.68
SiO_2	49.25
Al_2O_3	36.33
Fe_2O_3	.09
MnO	None
CaO	3.17
MgO	.64
K_2O	.26
Na_2O	2.16
	100.58

FERRUGINOUS ROCK FROM PENOKEE IRON RANGE,[1] WISCONSIN.

[Collected by R. D. Irving. Analysis by R. B. Riggs.]

SiO_2	15.62
Al_2O_3	4.27
Fe_2O_3	8.14
FeO	32.85
MnO	5.06
CaO	.81
MgO	2.66
CO_2	30.32
H_2O	.68
	100.41

[1] From NE. ¼ of Sec. 6, T. 45, R. 2 E.

TWO ROCKS FROM KAKABIKKA FALLS, KAMINISTIQUIA RIVER, ONTARIO, CANADA.

[Collected by R. D. Irving. Analyses by R. B. Riggs.]

A. Black slate, Animikie formation.
B. Material interstratified with the foregoing.

	A.	B.
SiO_2	37.73	54.26
Al_2O_3	3.41	2.57
Fe_2O_3	6.42	3.62
FeO	22.92	19.63
MnO	.40	.19
CaO	1.26	1.07
MgO	3.98	2.93
CO_2	18.01	14.93
H_2O	2.74	1.20
C	3.54	.45
	100.41	100.85

MICA ANDESITE FROM A CAÑON ON THE EAST SIDE OF SAN MATEO MOUNTAIN, NEW MEXICO.

[Collected by Capt. C. E. Dutton. Analysis by T. M. Chatard.]

Ignition	.14
SiO_2	65.78
TiO_2	.27
P_2O_5	.13
Al_2O_3	17.32
Fe_2O_3	3.68
FeO	.46
MnO	.32
CaO	1.66
MgO	.47
K_2O	4.64
Na_2O	5.23
	100.10

HYPERSTHENE ANDESITE FROM SAN FRANCISCO MOUNTAINS, ARIZONA.

[Collected by Capt. C. E. Dutton. Analysis by T. M. Chatard.]

Ignition	.20
SiO_2	64.82
TiO_2	.56
P_2O_5	.23
Al_2O_3	18.27
Fe_2O_3	3.48
FeO	.56
MnO	.20
CaO	2.89
MgO	.85
Na_2O	5.05
K_2O	2.67
	99.78

Alkalies undetermined. The color of the buff stone is due largely to organic or carbonaceous matter.

YELLOW SANDSTONE[1] FROM THE ARMEJO QUARRY, COLORADO.

[Analyses by T. M. Chatard.]

A. Analysis (partial) by treatment with strong hydrochloric acid.
B. Analysis by fusion with carbonate of soda.

	A.		B.
Insoluble in HCl	95.54	H_2O	1.19
Soluble:		SiO_2	81.27
Fe_2O_3 Al_2O_3	2.36	Al_2O_3	9.81
CaO	.17	Fe_2O_3	1.44
MgO	.34	CaO	.44
H_2O	1.19	MgO	.42
		Undet	5.43
	99.60		
			100.00

The undetermined portion under B was probably all alkalies.

EIGHT SAMPLES OF VOLCANIC DUST.

[Series A. From Gallatin Valley, Mont. Collected by A. C. Peale. Analyses by F. W. Clarke.]

[1. Dry Creek Valley, above mouth of Pass Creek. 2 and 3. From near Bozeman. 4. From near Fort Ellis.]

	1.	2.	3.	4.
H_2O	6.45	11.47	6.34	11.96
SiO_2	46.09	61.82	71.01	60.98
Al_2O_3, Fe_2O_3	14.35	19.86	15.17	21.69
CaO	1.61	1.78	1.19	1.83
$CaCO_3$	28.72	....	....	....
MgO	1.29	.51	.34	1.33
K_2O	1.47	1.31	2.97	1.23
Na_2O		2.38	2.77	.80
	99.98	99.13	99.79	99.82

[Series B. Material furnished by G. P. Merrill. Analyses by J. Edward Whitfield.]

[1. From Marsh Creek Valley, Idaho. 2. From Little Sage Creek, Montana. 3. From Devil's Pathway, Montana.]

	1.	2.	3.
H_2O lost at 105°	1.60	1.12	3.46
Ignition	6.00	6.50	5.60
SiO_2	68.92	65.56	65.76
Al_2O_3, Fe_2O_3	16.22	18.24	17.18
CaO	1.62	2.58	2.30
MgO	Trace	.72	Trace
K_2O	4.00	3.94	3.14
Na_2O	1.56	2.08	2.22
	99.92	100.74	99.66

[1] In use as a building stone.

[C. From mouth of Bazile Creek, Nebraska. Collected by J. E. Todd. Partial analysis by F. W. Clarke.]

Ignition	4.58
SiO_2	73.67
Al_2O_3 Fe_2O_3	14.33
CaO	.87
MgO	Trace
Alkalies	Undet.

LOESS AND CLAYS.

[Collected by Prof. T. C. Chamberlin. Analyses by R. B. Riggs. Material dried at 100°.]
[A. Typical loess, Kansas City, Mo.]

SiO_2	74.46
Al_2O_3	12.26
P_2O_5	.09
TiO_2	.14
Fe_2O_3	3.25
FeO	.12
MnO	.02
CaO	1.69
MgO	1.12
K_2O	1.83
Na_2O	1.43
H_2O (includes H of organic matter)	2.70
CO_2	.49
C. (organic)	.12
SO_3	.06
Cl	.05
	99.83

[B. Loess from 300 feet above the Mississippi River, 3½ miles northwest of Dubuque, Iowa.]

SiO_2	72.68
Al_2O_3	12.03
TiO_2	.23
P_2O_5	.72
Fe_2O_3	3.53
FeO	.96
MnO	.06
CaO	1.59
MgO	1.11
K_2O	2.13
Na_2O	1.68
H_2O (includes H of organic matter)	2.50
CO_2	.39
C (organic)	.09
SO_3	.51
Cl	.01
	100.22

[C. Loess from seven foot stratum over brown residuary clay, 350 feet above Mississippi River, near Galena, Ill.]

SiO_2	64.61
Al_2O_3	10.64
P_2O_5	.06
TiO_2	.40
Fe_2O_3	2.61
FeO	.51
MnO	.05
CaO	5.41
MgO	3.69
K_2O	2.06
Na_2O	1.35
H_2O (includes H of organic matter)	2.05
CO_2	6.31
C (organic)	.13
SO_3	.11
Cl	.07
	100.06

[D. Loess from center of the city, Vicksburg, Miss.]

SiO_2	60.69
Al_2O_3	7.95
P_2O_5	.13
TiO_2	.52
Fe_2O_3	2.61
FeO	.67
MnO	.12
CaO	8.96
MgO	4.56
K_2O	1.08
Na_2O	1.17
H_2O (includes H of organic matter)	1.14
CO_2	9.63
C (organic)	.19
SO_3	.12
Cl	.08
	99.62

[E. Red, putty-like clay with pebbles, Milwaukee, Wis.]

SiO_2	40.22
Al_2O_3	8.47
P_2O_5	.05
TiO_2	.35
Fe_2O_3	2.83
FeO	.48
MnO	Trace
CaO	15.65
MgO	7.80
K_2O	2.36
Na_2O	.84
H_2O (includes H of organic matter)	1.95
CO_2	18.76
C (organic)	.32
SO_3	.13
Cl	.06
	100.27

[F. Red pebble clay, from 15 feet below Lower Beach deposit, Milwaukee, Wis.]

SiO_2	48.81
Al_2O_3	7.54
P_2O_5	.13
TiO_2	.45
Fe_2O_3	2.53
FeO	.65
MnO	.03
CaO	11.83
MgO	7.05
K_2O	2.60
Na_2O	.92
H_2O (includes H of organic matter)	2.09
CO_2	15.47
C (organic)	.38
SO_3	.05
Cl	.04
	100.50

IRON ORES FROM LOUISIANA.

[Analyses by R. B. Riggs.]

[A. Brown hematite from Bossier Parish, one-half mile west of Bellevue.]

Ignition	11.06
SiO_2	27.85
Fe	39.65
S	.03
Mn	.126
P	.226

[B. Brown hematite from Dr. Whitlaw's, four miles west of Greenwood, Caddo Parish.]

Ignition	10.26
SiO_2	6.37
Fe	50.32
S	.10
Mn	.079
P	Trace

[C. Brown hematite from Simmons's bed, eight miles south of Homer, Claiborne Parish.]

Ignition	10.53
SiO_2	21.77
Fe	43.17
S	.26
Mn	.01
P	.382

[D. Brown hematite from Moreland's, nine miles southeast of Homer, Claiborne Parish.]

Ignition	10.62
SiO_2	10.97
Fe	52.18
S	.03
Mn	.026
P	.064

[E. Brown hematite from 500 feet east of Vienna wire road, Lincoln Parish.]

Ignition	9.05
SiO_2	23.20
Fe	44.54
S	.09
Mn	.006
P	.859

[F. Brown hematite from Lincoln Reed's place, nine miles northwest of Vienna.]

Ignition	9.50
SiO_2	28.12
Fe	39.26
S	.03
Mn	.049
P	.447

[G. Brown hematite from Webster, four miles northwest of Shangaloo.]

Ignition	11.25
SiO_2	18.72
Fe	45.72
S	.17
Mn	.007
P	.247

[H. Brown hematite from Union Parish, one and a half miles north of Downsville.]

Ignition	11.04
SiO_2	21.70
Fe	43.76
S	.03
Mn	.005
P	.835

[I. Brown hematite from Moreland's, ten miles southwest of Arcadia, Bienville Parish.]

Ignition	18.22
SiO_2	39.95
Fe	22.22
S	.17
Mn	.157
P	.072

[J. Limestone from Rayborn's Salt Lick, Bienville Parish.]

SiO_2	.55
$Fe_2O_3Al_2O_3$	1.61
P_2O_5	.048
MnO	Trace
CaO	54.09
MgO	.06
CO_2	44.12
SO_3	.05
	100.528

"NATURAL COKE" FROM MIDLOTHIAN, VA.

[Collected by I. C. Russell. Analysis by R. B. Riggs.]

Water	1.66
Volatile matter	18.35
Fixed carbon	67.13
Ash	12.86
	100.00
Sulphur	4.70

Water in coal dried forty-eight hours over sulphuric acid, 0.11 per cent. Water taken up in forty-eight hours' exposure over water, 3.90 per cent.

COAL FROM JEFFERSON COUNTY, WEST VIRGINIA.

[Bed about fifteen miles west of Berkeley Springs. Analysis by J. Edward Whitfield.]

Moisture	2.30
Volatile matter	10.90
Fixed carbon	81.20
Ash	5.60
	100.00
Sulphur	.785

No coke; ash, pink and sandy.

THREE COALS FROM GULF, NORTH CAROLINA.

[Collected by I C Russell. Analyses by F W. Clarke. Specific gravity determinations made with the Jolly balance by E. L. Howard.]

	Upper layer.	Middle layer.	Lower layer.
Volatile matter	24.48	24.22	23.94
Fixed carbon	72.44	67.86	66.37
Ash	3.08	7.92	9.69
	100.00	100.00	100.00
Sulphur	.99	1.42	3.33
Specific gravity	1.295	1.339	1.359

Coke, good; ash, gray. The coals gain weight on drying at 115°.

COAL FROM WALNUT COVE, STOKES COUNTY, NORTH CAROLINA.

[Analysis by J. Edward Whitfield.]

Water	.38
Volatile matter	17.99
Fixed carbon	55.47
Ash	26.16
	100.00
Sulphur	5.56

No coke. Residue sandy.

"NATURAL COKE" FROM PURGATORY CAÑON, NEW MEXICO.

[Analysis by R. B. Riggs.]

Volatile matter	16.87
Fixed carbon	74.18
Ash	8.95
	100.00
Specific gravity	1.43

TWO SPRINGS, ONE MILE FROM FARMWELL STATION, LOUDOUN COUNTY, VIRGINIA.

[Analyses by R. B. Riggs. Stated in grammes per liter.]

A.

	Found.	Per cent. of total solids.	Hypothetical combination.	
SO_4	1.2865	61.10	KCl	.0067
Cl	.0095	.45	$NaCl$	.0104
CO_3	.1590	7.55	Na_2SO_4	.2355
SiO_2	.0210	1.00	$MgSO_4$	.0750
Al_2O_3	.0070	.33	$CaSO_4$	1.5052
Ca	.5235	24.87	$CaH_2(CO_3)_2$	.1100
Mg	.0150	.71	$CaCO_3$	.1319
K	.0035	.17	Al_2O_3	.0070
Na	.0805	3.82	SiO_2	.0210
	2.1055	100.00		2.1027

B.

SO_4	1.4050	61.28	KCl	.0057
Cl	.0175	.76	$NaCl$	.0244
CO_3	.1730	7.55	Na_2SO_4	.2543
SiO_2	.0110	.48	$MgSO_4$	.0975
Al_2O_3	.0105	.46	$CaSO_4$	1.6363
Ca	.5610	24.47	$CaH_2(CO_3)_2$	.1438
Mg	.0195	.85	$CaCO_3$	.1107
K	.0030	.13	Al_2O_3	.0105
Na	.0920	4.01	SiO_2	.0110
	2.2925	99.99		2.2942

TWO ARTESIAN WELLS, STORY CITY, STORY COUNTY, IOWA.

[Analyses by F. W. Clarke, with carbonic acid determinations by R. B. Riggs.]

[A. Water from artesian well of Thorkill Henryson. Total solids, 0.3620 gramme to liter.]

	Found.	Per cent. of total solids.	Hypothetical combination.	
SiO_2	Trace		SiO_2	Trace
Fe_2O_3 Al_2O_3	.0135	3.73	Fe_2O_3, Al_2O_3	.0135
Cl	.0010	.27	NaCl	.0016
SO_4	None		Na_2CO_3	.0417
Ca	.0764	21.10	$CaCO_3$	.1910
Mg	.0324	8.95	$MgCO_3$	.1134
Na	.0187	5.17		
CO_2, total	.2680	CO_3 60.56		.3612
		99.78	(99.78 per cent. of total solids accounted for.)	

The CO_2 required in the second and third columns is 0.1607 gramme, leaving 0.1083 gramme for bicarbonates. The water contained flakes of ferric hydroxide.

[B. Water from artesian well of Charles Watkins. Total solids, 0.4710 gramme to liter.]

	Found.	Per cent. of total solids.	Hypothetical combination.	
SiO_2	.0250	5.31	SiO_2	.0250
Fe_2O_3	.0060	1.28	Fe_2O_3	.0060
Ca	.0796	16.90	$CaCO_3$	.1990
Mg	.0356	7.56	$MgCO_3$	.1246
Na	.0501	10.64	Na_2CO_3	.1155
K	Trace	CO_3 58.12		
				.4701
Cl	Trace	99.81	(99.81 per cent. of total solids accounted for.)	
CO_2, total	.3920			

The CO_2 required in the second and third columns is .2008 gramme, leaving .1912 gramme for bicarbonates. The water contained much sediment. Neither water contained any sulphates.

BECK'S HOT SPRINGS, NEAR SALT LAKE CITY, UTAH.

[Analysis by R. B. Riggs. Stated in grammes per liter.]

	Found.	Per cent. of total solids.	Hypothetical combination.	
SO_4	.8405	6.68	KCl	.3761
Cl	6.7438	53.59	NaCl	9.5506
CO_3	.2045	1.63	$MgCl_2$	.4334
SiO_2	.0315	.25	$CaCl_2$	.6957
Al_2O_3	.0090	.07	$CaSO_4$	1.1907
Ca	.6943	5.52	$CaCO_3$	.1262
Mg	.1095	.85	$CaH_2(CO_3)_2$	.1739
K	.1969	1.57	Al_2O_3	.0090
Na	3.7549	29.84	SiO_2	.0315
Li	Trace			
B_2O_3	Trace			12.5871
	12.5849	100.00		

WATER OF MONO LAKE, CALIFORNIA.

[Analysis by T. M. Chatard. Compare old analysis in Bulletin 9, p. 26. Stated in grammes per liter. Specific gravity, 1.0456, 17.°5.]

	Found.	Per cent. of total solids.	Hypothetical combination.	
Na	19.6853	36.790	KCl	1.8342
K	.9614	1.795	NaCl	18.5068
Ca	.0200	.037	Na_2SO_4	9.8690
Mg	.0551	.103	Na_2CO_3	18.6720
Al_2O_3, Fe_2O_3	.0030	.005	$NaHCO_3$	3.9015
SiO_2	.0700	.130	$Na_2B_4O_7$	.2000
SO_4	6.6720	12.470	$CaH_2(CO_3)_2$	.0810
Cl	12.1036	22.630	$MgH_2(CO_3)_2$	.3349
B_4O_7	.1600	.300	Al_2O_3,Fe_2O_3	.0030
CO_2	10.0396	18.770	SiO_2	.0700
O for CO_3	3.2341	6.090		
H_2O in bicarbonates	.4683	.880		53.4724
	53.4724	100.000		

The boric acid is cited from the old analysis, as the material was insufficient for a new determiation.

INDEX.

NOTICE.

The bulletins of the United States Geological Survey are numbered in a continuous series and will be bound in volumes of convenient size.

This bulletin will be included in Volume VII.

DEPARTMENT OF THE INTERIOR

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No. 43

ON THE TERTIARY AND CRETACEOUS STRATA OF THE TUSCALOOSA, TOMBIGBEE, AND ALABAMA RIVERS

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ADVERTISEMENT.

[Bulletin No. 43.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Second Annual Report of the United States Geological Survey, 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 62 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

VI. Sixth Annual Report of the United States Geological Survey, 1884–'85, by J. W. Powell. 1886. 8°. xxix, 570 pp. 65 pl. and maps.

The Seventh and Eighth Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, IX, X, XI, and XII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-Bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

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IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price $1.15.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 243 pp. 56 l. 56 pl. Price $2.70.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl. Price $1.75.

XII. Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons. 1886. 4°. xxix, 770 pp. 45 pl. and atlas of 35 sheets folio. Price $8.40.

The following is in press:

XIII. Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker.

The following are in preparation:

I. The Precious Metals, by Clarence King.

— Gasteropoda of the New Jersey Cretaceous and Eocene Marls, by R. P. Whitfield.

— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

— Lake Bonneville, by G. K. Gilbert.

— Sauropoda, by Prof. O. C. Marsh.

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— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.

— Report on the Denver Coal Basin, by S. F. Emmons.

— Report on Silver Cliff and Ten Mile Mining District, Colorado, by S. F. Emmons.

— Flora of the Dakota Group, by J. S. Newberry.

— The Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley, by J. S. Newberry.

BULLETINS.

Each of the Bulletins contains but one paper and is complete in itself. They are, however, numbered in a continuous series, and may be bound in volumes of convenient size. To facilitate this, each Bulletin has two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 43 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining values of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A Catalogue of Geological Maps of America (North and South), 1752-1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. Report of work done in the Washington Laboratory during the fiscal year 1883-'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary Studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin, with Descriptions of New Forms, by R. Ellsworth Call. Introduced by a Sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the Higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

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17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

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20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

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23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American Localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the Neighborhood of Baltimore, Md., by George H. Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second Contribution to the Studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. A Systematic Review of our Present Knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a Preliminary Study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

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36. Subsidence of Fine Solid Particles in Liquids, by Carl Barus. 1887. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

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41. Fossil Faunas of the Upper Devonian — the Genesee Section, New York, by Henry S. Williams. 1886. 8°. 121 pp. 4 pl. Price 15 cents.

42. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist. 1887. 8°. 152 pp. 1 pl. Price 15 cents.

43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson. 1887. 8°. 189 pp. 21 pl. Price 15 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V; Numbers 37 to 41, Volume VI. Volume VII is not yet complete.

The following are in press:

44. Bibliography of North American Geology for 1886, by Nelson H. Darton. 1887. 8°. 35 pp. Price 5 cents.

45. Present Condition of Knowledge of the Geology of Texas, by Robert T. Hill. 1887. 8°.

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— The Gabbros and Associated Rocks in Delaware, by F. D. Chester.
— Report on the Geology of Louisiana and Texas, by Lawrence C. Johnson.
— Fossil Woods and Lignites of the Potomac Formation, by F. H. Knowlton.
— Contributions to the Mineralogy of the Pacific Coast, by W. H. Melville and Waldemar Lindgren.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

In press:

— Mineral Resources of the United States, 1886, by David T. Day. 1887. 8°.

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TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *November* 30, 1887.

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UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

TERTIARY AND CRETACEOUS STRATA

OF THE

TUSCALOOSA, TOMBIGBEE, AND ALABAMA RIVERS

BY

EUGENE A. SMITH

AND

LAWRENCE C. JOHNSON

WASHINGTON

GOVERNMENT PRINTING OFFICE

1887

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CONTENTS.

ILLUSTRATIONS.

PREFACE.

During the summer of 1883 a trip was made by the authors, in a small steamer, down the Tuscaloosa (also called Black Warrior or Warrior) River, from Tuscaloosa to its confluence with the Tombigbee, down the latter stream to its confluence with the Alabama, down the Alabama and Mobile Rivers to the head of Mobile Bay, and thence up the last two rivers to Prairie Bluff. This route, the localities of the accompanying detailed sections, and other points mentioned in the text are indicated in the accompanying geologic map of Alabama forming Plate XI. The trip by steamer was made at the joint expense of the U. S. Geological Survey and the Geological Survey of Alabama.

The first draft of this bulletin was prepared with the data collected during this trip, there being added thereto information gathered by myself in 1872, 1880, 1881, 1882, and 1884 for the Geological Survey of Alabama and for the Tenth Census of the United States and information obtained by Mr. L. C. Johnson in 1881, 1882, and 1883. The bulletin was not completed until I had gone over the whole ground again, in the summer of 1885, in company with Messrs. T. H. Aldrich and D. W. Langdon, of the Geological Survey of Alabama. Finally, the results of my investigations in the same region during the summer of 1886 have been in large part incorporated. Though it is believed that the accompanying sections of the Tertiary and Cretaceous strata of Alabama are much more nearly complete and more trustworthy than anything hitherto published, it should be said that the paleontologic material has not yet been fully examined, and that the Ripley, Eutaw, and Tuscaloosa formations require some further investigation. The present report must, therefore, be regarded as a preliminary one.

The photographic views from which some of the illustrations have been prepared were taken during the summer of 1885. It is greatly to be regretted that some of the photographic plates of important localities were spoiled by dampness before prints could be obtained from them.

The authors desire to express their indebtedness to Mr. W J McGee, of the U. S. Geological Survey, for assistance kindly given in the

the collections recently made by Mr. T. H. Aldrich, but not yet described, show that there are very few fossils severally peculiar to any of these quasi-formations; and we are disposed to refer the several strata to the Upper Eocene. We are also led to divide the Claiborne of Hilgard into two formations, corresponding to his Calcareous Claiborne and Silicious Claiborne, respectively, and to restrict the term to the upper. We follow Tuomey[1] and others in denominating the lower formation the Buhrstone. Again, we are unable to discriminate the Lagrange and the Flatwoods of Hilgard; and we find the formation including these divisions to include also several beds containing marine fossils.[2]

The three Cretaceous formations are easily distinguishable along our rivers as distinctive rock masses; but in constructing our sections we have been constantly confronted with the difficulty of fixing their boundaries with precision, since they appear to shade into one another, lithologically at least, by almost imperceptible gradations. Thus we are not sure that any of the outcrops along either of the rivers show the contact of the Ripley beds with the upper part of the Rotten Limestone. The contact of the lowermost strata of the latter formation with the underlying sandy beds is clearly enough seen at several places, at Erie and Choctaw Bluff, Tuscaloosa River, and at House Bluff, Alabama River, &c.; but below the first 15 or 20 feet of these sands the strata for nearly 300 feet (and, indeed, to the base of the Tuscaloosa formation, perhaps 1,000 feet lower still) are exceedingly poor in fossil remains, except those of vegetable origin, and even these are almost indeterminable. Dr. Hilgard considers these fossiliferous sands (his Tombigbee Sand group) as more nearly allied to the Rotten Limestone than to the Eutaw group, and if we class them with the former then the line between the Rotten Limestone and the Eutaw groups will come somewhere within the first 20 feet or so below the base of the calcareous part of the Rotten Limestone. The limit between the Eutaw and the Tuscaloosa formation, in like manner, is ill defined. It may further be mentioned that we have not seen in Alabama any beds which we can identify as belonging to the Grand Gulf age.

Our estimates of thicknesses vary considerably from those of Hilgard, partly, at least, because his estimates do not represent the thick-

[1] First Bien. Rep. Geol. of Ala., p. 143, 1850.

[2] This formation has been denominated Eolignitic by Heilprin (Proc. Acad. Nat. Sci. Phila., p. 159, 1881); but the law of priority demands the retention of the name Lignitic, which was used in the same sense by Hilgard in 1860 or earlier. Once more, we feel compelled to restrict the name Eutaw to the glauconitic sands, laminated clays, micaceous sands, &c., beneath the Tombigbee sand and above the Big Log Shoals horizon. And, finally, for reasons stated fully on a subsequent page, we apply the name Tuscaloosa formation to the fossiliferous clays, purple clays and associated rocks exposed on the Tuscaloosa River from Tuscaloosa to White Bluff and at many localities between the Tuscaloosa and Alabama Rivers.

ness at any one locality, but the maxima in the Gulf States, and partly because our estimates are based on careful measurements of actual exposures of which only a part have hitherto been examined.

Since our route described two approximately parallel lines at right angles to the strike of the strata, we have generally been able to supply the breaks in continuity of exposures along one river by satisfactory exposures at corresponding stratigraphic horizons on the other, or at some points inland but contiguous to the water courses.

In the Tertiary formations at two horizons only have we been unable, by the combination of undoubtedly overlapping sections, to perfect our stratigraphic column. These breaks, which, upon an assumed uniform dip of 30 to 40 feet to the mile, cannot involve more than 50 feet each, probably much less, we have left blank. The black clays at the base of the Tertiary are exposed along the Tombigbee River from Black Bluff to Naheola, a distance which, with such a dip as that assumed, would correspond to a thickness of 260 feet.[1] These clays are much thinner on the Alabama River, and in the Bladen Springs boring, as we interpret it, the thickness is about 100 feet, which we have adopted in our section. The apparently much greater thickness indicated by the exposures along the Tombigbee is probably due to undulations in the strata.

Our estimate of the total thickness of the Tertiary formations, ranging from 1,630 to 1,700 feet, is considerably larger than any hitherto made. It is, however, a minimum, as may be seen from our plates giving the overlapping sections from which the stratigraphic column has been constructed. This estimate finds a strong corroboration in the records of borings made in Meridian, Miss., and at Bladen Springs, Ala. The former boring was commenced in the upper strata of the Lignitic, just beneath the Buhrstone, and it is certain that the Rotten Limestone of the Cretaceous was not reached at a depth of 980 feet. At Bladen Springs the surface rocks are the Hatchetigbee beds, immediately underlying the Buhrstone. In this boring the Rotten Limestone was reached at 1,220 feet and the boring terminated in that formation at a depth of 1,345 feet Accordingly, while our estimates of the aggregate thickness of the Tertiary formations of the Alabama and Tuscaloosa Rivers doubtless include minor errors, we have, we believe, a nearly complete and generally accurate section of the strata exposed on these rivers.

In the case of the Cretaceous our observations have less completely covered the ground, and we have been forced in some instances to rely upon estimates based upon an assumed seaward dip of the strata of 40 feet to the mile. This rate of dip agrees with the average of our obser-

[1] A re-examination of the exposures of these black clays in the summer of 1886 has convinced me that no reliance can be placed upon the dip in estimating the thickness, for the clays undulate very considerably. One bed in the black clay, for instance, was traced down the river (across the strike) for several miles, with scarcely any change in its height above the water level.—E. A. S.

vations and is corroborated by the record of the boring for an artesian well at Livingston, in Sumter County. The thickness of Rotten Limestone penetrated in this boring is 930 to 950 feet, and the width of the belt in which this is the surface rock in this part is about twenty-four miles across the strike of the strata. In the Ripley division we have, we think, a nearly complete section from our observations. In the Rotten Limestone we have the record of the Livingston well. In the Eutaw formation we have to rely in some degree upon estimates, though we have at Eutaw, on the Tuscaloosa, and at House Bluff and at Cunningham Bluff, on the Alabama, as we believe, nearly if not quite the complete series.

The materials of the Tuscaloosa formation, clays and loose sands, make comparatively little show along the Tuscaloosa River. Our column of this formation is accordingly very imperfect, and the estimate of thickness is based altogether upon an assumed dip of the strata of 40 feet to the mile.

The following table exhibits, in condensed form, our subdivisions of the Tertiary and Cretaceous formations of Alabama as exposed along the Tuscaloosa, Tombigbee, and Alabama Rivers, together with the carefully estimated thickness of each:

				Feet.
Tertiary (Eocene).	Upper	White Limestone	Coral Limestone (Vicksburg ?)	150
			Vicksburg (orbitoidal)	140
			Jackson	60
	Middle.	Claiborne		140–145
		Buhrstone		300
	Lower	Lignitic	Hatchetigbee	175
			Wood's Bluff	80–85
			Bell's Landing	140
			Nanafalia	200
			Matthews's Landing and Naheola	130–150
			Black Bluff	100
			Midway	25
Cretaceous		Ripley		250–275
		Rotten Limestone		1,000
		Eutaw		300
Cretaceous (?)		Tuscaloosa		(?) 1,000

Our investigations relate chiefly to the formations below the White Limestone, and more especially to those underlying the Buhrstone, of which, so far as we are aware, no connected account has hitherto been published.

Our itinerary notes have been assembled and digested and the various exposures of the two water ways are described together in the inverse order of antiquity. The leading phenomena are recapitulated in the description of the general section.

I.—TERTIARY STRATA.

§1. THE WHITE LIMESTONE.

As already stated, we include in this formation both the Vicksburg and the Jackson group of Conrad, Hilgard, and others, as well as the Red Bluff group of Hilgard, if it is developed in Alabama. The recent very extensive collections of Mr. T. H. Aldrich have shown that, with very few exceptions, the same shells are common to the Vicksburg and to the Jackson bed. Certain lithological and paleontological differences may easily be observed in the different parts of this formation, as set forth below, but these differences do not, in our opinion, justify us in dividing a formation which, in Alabama, so clearly presents itself as a unit. The term White Limestone has been used by Professors Tuomey and Winchell and by other geologists as representing both of the above groups, though most of the writers on Alabama Tertiary geology have called attention to certain differences existing between the upper and the lower parts of the formation as exhibited at the bluff at St. Stephens. The term, moreover, is popularly used to designate this whole series of limestone rocks throughout the region in which it occurs. As above stated, it is in this sense that we also wish to use it, and we do not intend to confine the term, as does Heilprin, to the lower 60 feet, which corresponds to the Jackson division.

The thickness of the White Limestone in Alabama we believe to be not less than 350 feet, and our estimates are based upon the following facts: About half a mile from the Claiborne bluff, on the road to Perdue Hill, White Limestone filled with *Orbitoides Mantelli* Mort. occurs at least 200 feet above the base of the argillaceous White Limestone (Jackson) which immediately overlies the Claiborne fossiliferous sands. At this locality, therefore, we have undoubtedly 200 feet of limestones belonging to this division of the Tertiary. At Salt Mountain, 150 feet of a coral limestone overlies the uppermost of the beds with *Orbitoides Mantelli*, and this, added to the orbitoidal and argillaceous limestones seen at Claiborne, gives what we consider to be the minimum thickness of the White Limestone.

As regards the classification of the White Limestone in the Tertiary series, opinions vary. Conrad says:[1] "The Claiborne group I regard as newer Eocene, the Jackson as older Oligocene, and the Vicksburg group as newer Oligocene."

Heilprin[2] also puts the Vicksburg and the Jackson together as Oligocene, though elsewhere in the same volume he speaks of the Vicksburg alone as Oligocene and places the Jackson with the Eocene as its uppermost member.

[1] Geol. N. C., Vol. I, Appendix A, p. 25, 1875.

[2] Contrib. to the Tert. Geol. and Pal. of the U. S., p. 38.

The view of Conrad was at first adopted by us, but subsequently the study of extensive collections made by Mr. Aldrich at Jackson and Vicksburg, the finding by him of *Venericardia planicosta* in the uppermost beds of the White Limestone near Claiborne, and other circumstances have led us to think that there is no good reason for separating any part of our White Limestone from the Eocene, and we have no strata in Alabama which we regard as Oligocene.

It is to be remarked that nowhere in Alabama have any deposits yet been found comparable with the fossiliferous beds of Jackson and Vicksburg in Mississippi, as regards either the excellence of preservation or the number and variety of the fossils; for, with the exception of *Orbitoides Mantelli*, *Pecten perplanus* Mort., *Zeuglodon cetoides*, and a few others, fossils are comparatively rare in the Alabama White Limestone.

DIVISIONS OF THE WHITE LIMESTONE.

The few forms, however, which do occur here appear to be generally restricted to a definite horizon, and we recognize in every locality of its occurrence two divisions of the White Limestone, and in one place three divisions, each distinguished by peculiarities in its lithological characters and in its fossils.

The *uppermost division*, 150 feet in thickness, has as yet been observed in one locality only, viz, at Salt Mountain at the Middle Salt Works in Clarke County. The rock here, is a hard, white limestone, composed in great measure of masses of corals partly silicified. Near the base of this rock there occur great numbers of the spines and plates of echinoderms.

The *middle division* of the White Limestone has a thickness of at least 140 feet. Lithologically it varies considerably, being in part a hard, crystalline limestone weathering into rough, irregularly shaped pieces, which have suggested the name "horsebone" rock, popularly used to designate it. Another variety is a soft, sometimes pulverulent mass of nearly pure carbonate of lime, which is everywhere quarried for building purposes. When fresh, this rock may easily be cut with an ax or a saw, but it hardens on exposure to the air and lasts for many years in chimneys and pillars to houses. This part of the White Limestone contains as a characteristic fossil *Orbitoides Mantelli*, often in such numbers that the rock is little more than a mass of the disks of orbitoides packed in soft, white carbonate of lime. The orbitoides are most abundant in the upper two thirds of this division, becoming less and less abundant below this.

The *lower division* of the White Limestone, about 60 feet in thickness, is in general terms a light colored, argillaceous limestone resembling the Rotten Limestone of the Cretaceous formation both in the character of the rock and in that of the soils to which it gives rise on disintegration. It is traversed by thin bands of tolerably pure, white limestone and by beds of slightly calcareous clay, the latter often impreg-

nated with gypsum. In places it is strongly glauconitic. This division contains a greater variety of fossils than either of the other two, though probably a smaller number. The fossils appear in general to be much more abundant in the upper half of the rock, where the more commonly occurring species are *Pecten perplanus* Mort., *Spondylus dumosus* Mort., *Ostrea cretacea* Mort., sharks' teeth, bones of *Zeuglodon cetoides*, and *Terebratula lachryma* Mort. This upper and most highly fossiliferous part holds calcareous clays which are strongly phosphatic and occasionally well filled with phosphatic or coprolitic nodules. The lower half of this division, while less fossiliferous than the preceding, has in nearly every locality examined a bed near its base at least three feet in thickness holding vast numbers of *Scutella Lyelli* Con. This, which we have called the Scutella bed, has often served us as a guide in the study of this formation in the field, since it overlies by a few feet only the Claiborne fossiliferous sands.[1]

This lower division of the White Limestone has usually been considered the equivalent of the Jackson, and the overlying orbitoidal rock (middle division) the equivalent of the Vicksburg group of Mississippi, and there seems to be no reason to doubt the correctness of the identification. The uppermost division has been observed or recognized only at one locality (Salt Mountain), but it will probably be found to belong to the Vicksburg group.

The following sections (see Plate XII, p. 143) exhibit the characters of two phases of the White Limestone as they are exposed along the two rivers, and a third phase seen in the lower part of Clarke County between the rivers.

(*a*) About six miles south of Jackson, in Clarke County, at the Central Salt Works, I obtained in the summer of 1885 a section of the uppermost of the White Limestone rocks which overlie the orbitoidal rock. These rocks, which are seen in actual contact with the orbitoidal limestone, form the summit of the White Limestone formation in Alabama, so far, at least, as our observation goes. At this locality, Salt Creek flows at the base of a hill rising 150 feet above the water level and composed of limestone in which the only recognizable fossils are spines and plates of echinoderms and great masses of corals. These corals make up a very considerable proportion of the hill. A few hundred yards from the base of the hill a thickness of about twenty feet of the orbitoidal rock, such as is used in the vicinity for building purposes, is exposed, and in such position as to show unmistakably that it underlies the coral rock of the hill just mentioned, which has the local name of Salt Mountain. (See Plate XII, Fig. 1, p. 143.)

[1] The rocks of the Claiborne group are distinguished from those of the White Limestone by the presence of glauconite in large proportion, and this Scutella bed is the first of the ferruginous beds of the Tertiary. We are undecided whether this Scutella bed should go with the White Limestone or with the Claiborne, since the fossil is found in both formations.

(*b*) The bluff at Saint Stephens on the Tombigbee River (Plate II), about one hundred feet in height, exhibits both of the commonly occurring phases of the White Limestone, viz, the middle and lowermost. (See Plate XII, Fig. 2, p. 143.) The uppermost 70 feet of this bluff consists of the soft White Limestone, which is extensively quarried for building chimneys. *Orbitoides Mantelli* occurs throughout this rock, but is particularly abundant in the uppermost 20 or 30 feet. Below the orbitoidal rock to the water's edge the limestone is rather argillaceous and holds in places great numbers of *Spondylus* (*Plagiostoma*) *dumosus* and other fossils which are usually considered characteristic of the Jackson group. In this part of the bluff, Mr. D. W. Langdon, jr., of the Alabama Geological Survey, in 1884 discovered phosphatic nodules and a phosphatic marl, a more detailed description of which will be found in a forthcoming Alabama State Geological Report. In this connection it may be proper to say that in the summer of 1885 we found that a phosphatic marl occurs in the lower or Jackson division of the White Limestone everywhere in Choctaw, Clarke, and Monroe Counties.

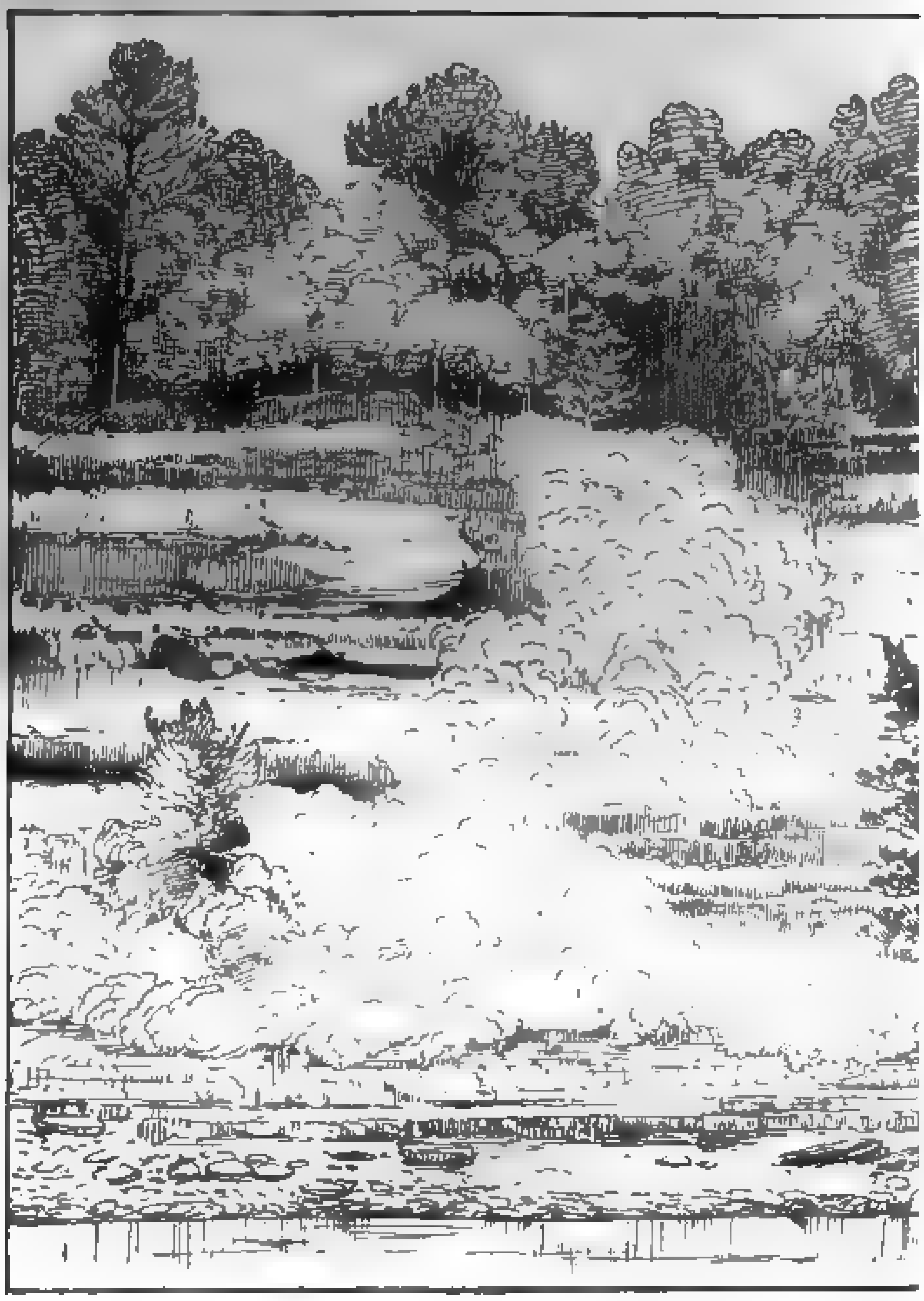
(*c*) About half a mile above Saint Stephens Bluff, and in plain sight of it, is Gopher or Baker's Hill, where the actual contact of the limestones of Saint Stephens Bluff with the ferruginous sands of the Claiborne formation may be clearly seen.

The following section of Baker's Hill should set forever at rest the question of the relative positions of the strata concerned (see Plate XII, Fig. 3, p. 143).

Section at Baker's Hill, Tombigbee River.

1. Orbitoidal limestone forming summit of the hill. This limestone is the same as that forming the upper part of the Saint Stephens Bluff, half a mile distant .... 20 to 30 feet.
2. Argillaceous limestone with *Pecten perplanus* Mort. and *Pecten Poulsoni* Mort. in its upper part and with hard ledges in lower part .... 55 to 60 feet.
   This rock is the same as that at the base of Saint Stephens Bluff, but only 15 to 20 feet of it are to be seen above water at the latter place.
3. Bed with *Scutella Lyelli* in great numbers, 1 foot seen, at other points .... 3 feet.
4. Coarse grained, ferruginous sands, passing downwards into reddish, ferruginous sands, with the characteristic fossils of the Claiborne sands, viz, *Melongena alveata* Con., *Crepidula lirata* Con., *Infundibulum trochiformis* Con., *Corbula Murchisoni* Lea, *Turritella lineata* Lea, *Cytherea æquorea* Con., *Oliva Alabamensis* Con., *Turbinella pyruloides* Con., *Turbinolia Maclurei* Lea, *Voluta Defrancki* Lea, *Astarte sulcata* Lea, &c .... 15 to 18 feet.
5. Bluish green, glauconitic sands and clayey sands containing a *Flabellum* similar to that found at Claiborne and at Coffeeville .... 8 to 10 feet
6. Hard ledge at water's edge at upper end of bluff .... 1 foot.

(*d*) During the summer of 1885 many localities were visited in Choctaw and Clarke Counties where the White Limestone and the Claiborne sands are to be seen in contact, so that there can be no possible doubt as to their relative position, unless we assume that the strata have been overturned, and of this there is not a shadow of proof. Some of the localities were also visited by Professor Tuomey and by Prof. A.



OBEE RIVER

Winchell, while some have not yet been referred to in any published document. These localities will be given below, under Claiborne group.

Professor Tuomey[1] says that the Buhrstone, after dipping below the surface in the upper part of Clarke County, emerges again at the Lower Salt Works, in the southern part of the county. Our visit to this place in 1883 confirmed this statement of Professor Tuomey, but there were many things observed in the distribution of the rocks in Clarke and Choctaw Counties which were difficult of explanation so long as we confined our attention to the banks of the rivers.

During several excursions by land through these counties previous to 1883 and again in the summer of 1885, the present writer was able to collect the data which prove that the basin in Clarke County, referred to by Professor Tuomey, is by no means a simple syncline, but includes several undulations, by which the Buhrstone rocks are again brought to the surface of the country at several points to the southward of the line where they first dip below it. It is by reason of these irregularities that the southernmost exposures of the Tertiary rocks along the rivers are not made by the uppermost rocks of the White Limestone series, but in the case of Choctaw Bluff, at least, by those of the Jackson or lower division of the White Limestone.

Section at Choctaw Bluff, Clarke County.

1. Drift, pebbles and sand, capped with red loam........................20 feet.
2. Bluish clay..5 feet.
3. Greenish clay..5 feet.
4. White argillaceous limestone or indurated marl, containing many large specimens of *Ostrea Georgiana*, *Scutella Lyelli*, *Pecten Poulsoni*, many tubes of *Aspergillum* or allied genus, and obscure casts of other fossils........................5 feet.

The bluish clay (No. 2) contained in many places lignitized or half lignitized stumps, while the underlying greenish clay contained no fossils.

At Gainestown, a few miles above Choctaw Bluff, there is another exposure of the White Limestone. The principal rock at this place is a heavy bedded, yellowish limestone with *Orbitoides Mantelli*. This rock has been quarried for building purposes, and several large blocks of it are to be seen on the river bank at Choctaw Bluff, whither they were carried during the war. The tubes of Aspergillum are also to be seen at several places near Gainestown, and some of the clays there hold a very considerable amount of gypsum crystals, as described by Mr. E. Q. Thornton,[2] who also says that the bones of Zeuglodon have been found a few miles from the Gainestown Landing. From these circumstances it appears that a part, at least, of the strata at Gainestown is of the Jackson horizon.

(*e*) From Marshall's Landing, some miles above Gainestown, up to Claiborne, the bluffs on both sides of the river give a very complete

[1] First Bien. Rep. Geol. Ala., p. 150, 1850.

[2] Second Bien. Rep. Geol. Ala., pp. 250 251, 1858.

and almost uninterrupted section, with none of the irregularities noticed on the Tombigbee, since all the strata show a gentle southerly dip.

At Marshall's Landing, the upper part of the bluff consists of the orbitoidal limestone, the lower part of the argillaceous limestone of Jackson age, and from this point up to the mouth of Cedar Creek the other beds of the Jackson series form the low bluffs of the river, from which a very good section has been made, as follows:

Section of White Limestone strata, Alabama River.

1. Orbitoidal White Limestone of the usual character ....10 feet.
2. White Limestone containing *Scutella Lyelli* in numbers............ ......10 feet.
   This is the base of the Vicksburg or Orbitoidal Limestone, which, as we have seen at Claiborne, has a thickness of 140 feet, and at Salt Mountain has 150 feet of a coral limestone above it.
3. Effervescent or calcareous, joint clay, in two beds, each 5 or 6 feet in thickness, separated by 3 feet of soft, earthy White Limestone; below this a harder ledge of limestone, and then about 8 feet of blue clay, passing into a blue, calcareous clay or marl, making in all ....about 24 feet.
4. Earthy white limestone, resembling the Rotten Limestone of the Cretaceous formation ....about 25 feet.
   (This limestone has at intervals of 3 or 4 feet, ledges of similar but harder material projecting slightly from the faces of the bluff. These ledges vary from one to three feet in thickness.
5. Scutella bed (*S. Lyelli*), consisting of 3 layers: (*a*) a limestone, with a few *Scutellas* (*S. Lyelli*), 1 foot; (*b*) a ferruginous sand filled with the same *Scutella*, 1 foot; (*c*) a white limestone bed similar to (*a*) and 1 foot thick .... 3 feet.
   Beneath this is a bed of coarse grained, ferruginous sand, extending down to the water ....1 or 2 feet.
   This bed is seen at Rattlesnake Bluff, Claiborne.

These relations are shown in the section. (See Plate XII, Fig. 4, p. 143.)

(*f*) The upper part of the bluff at Claiborne is also composed of the argillaceous White Limestone of the Jackson age, and as we ascend the hill back of Claiborne, leading up to Perdue Hill (2 miles), the orbitoidal limestone appears in gullies and wherever the surface soil has been removed, up to an elevation of 90 or 100 feet above the top of the river bluff. This is precisely the position which the White Limestone occupies with reference to the Claiborne sands at Baker's Hill on the Tombigbee, as well as at other localities in Clarke County, referred to above. (See Plate XII, Fig. 5, p. 143.)

The White Limestone is the surface rock over a very considerable part of Choctaw, Washington, Clarke, Monroe, Conecuh, Covington, and Geneva Counties. Where the lower or more argillaceous portion of it forms the surface, it gives rise, upon disintegration, to a limy soil, very similar to that of the Rotten Limestone of the Cretaceous group, but the topography is much more broken, justifying the name of Lime Hills, which I have given to this region in the Report of the Geological Survey of Alabama for 1881–'82. These Lime Hills may be followed from Choctaw and Washington Counties, without a break, into

Mississippi, and there can be no doubt as to their identity with the Jackson prairies of Professor Hilgard.

It is in these Prairie Hills that the Zeuglodon bones are always found. Other commonly occurring fossils are *Pecten perplanus*, *Spondylus dumosus*, *Scutella Lyelli*, a species of Ostrea, and a Cassis similar to one occurring at Red Bluff in Mississippi.

§ 2. THE CLAIBORNE.

The beds which in Alabama intervene between the base of the White Limestone and the top of the Lignitic division, and which are at least 450 feet in thickness, may be divided into two groups, of very unequal thickness, which exhibit very marked differences in their lithological features and in the relative abundance and variety, though perhaps not in the specific characters, of their fossil contents.

The upper group, 140 to 150 feet in thickness, constituting the *Claiborne beds proper*, consists of ferruginous sands, calcareous sands, and calcareous clays, generally glauconitic. These beds are mostly loose and incoherent, crumbling easily and giving rise to no marked topographic features in the region which they immediately underlie. This whole group is distinguished by the abundance and the variety of its fossils. Near the top of the series is the bed of ferruginous sand which has furnished the greater part of the celebrated Claiborne fossils. The calcareous sands underlying for 60 feet the ferruginous Claiborne sand above named are clearly marked by the great numbers of the shells of *Ostrea sellæformis* which they contain. Below these beds are glauconitic sands and clays holding a great variety of well preserved shells.

The lower group, about 300 feet thick, consists of silicious and aluminous sandstones and indurated clays, with occasional glauconite beds; all, except a few thin beds with marine shells, containing very little lime and, by comparison with the preceding group, very few fossils. These rocks are mostly hard and resistant and form some of the highest and most rugged hills in the southern part of the State. To this series of rocks Professor Tuomey[1] has given the name *Buhrstone*, and has pointed out their identity with the Buhrstone rocks of South Carolina and Georgia.

Prof. E. W. Hilgard[2] placed these two together under the head of the Claiborne group, distinguishing the upper and lower divisions as the Calcareous and the Silicious Claiborne strata, respectively. From the section given in Hilgard's Report,[3] it seems that the middle part of what we have called the Claiborne series, containing the great numbers of *Ostrea sellæformis*, are the beds of the Calcareous division, best developed in that State. The Silicious Claiborne or Buhrstone strata are found in

[1] First Bien. Rep. Geol. Ala., p. 150, 1850.
[2] Rep. on Geol. and Agric. of Mississippi, pp. 108, 123, and 126, 1860.
[3] Rep. on Geol. and Agric. of Mississippi, pp. 126, 127, 1860.

great thickness in Mississippi and present practically the same features as in Alabama. The rugged Buhrstone hills of Clarke, Lauderdale, Newton, Kemper, Neshoba, and Leake Counties, in Mississippi, have their counterparts in Choctaw, Clarke, and Monroe Counties in Alabama.

The fossiliferous greensands mentioned by Professor Hilgard,[1] in connection with the Silicious Claiborne, were afterwards (1871) traced by the writer from Marion, in Mississippi, across the State to the Mississippi bottom in Holmes and Carroll Counties.

As already indicated above in our tabular presentation, we adopt here Professor Tuomey's division of these strata into Claiborne and Buhrstone.

The lithological and other characters of the Claiborne beds have been stated above in the most general terms. A few additional details will suffice to give a fair conception of the general features of the Claiborne formation. Near the top of the series we find a bed varying from 15 to 17 feet in thickness, which, at Claiborne, Gosport, Rattlesnake Bluff, and Baker's Bluff, is a reddish yellow, ferruginous sand, literally packed with the most beautifully preserved fossils. In many parts of Clarke and Monroe Counties, where this bed has undergone less change from exposure to the atmospheric agencies, these sands are mixed with a very considerable proportion of glauconite, and the color is a very decided dark green, instead of reddish yellow. This bed we have called the Claiborne Fossiliferous Sand. Below it are some 60 feet of calcareous clays and calcareous sands, the former making the upper 25 feet, characterized by a bluish color, shading into light gray below. The calcareous sands make up the lower 35 feet, and they are of a light yellowish color. The whole of this 60 feet of strata, except perhaps some 10 feet of blue clay near the top, is distinguished from all the other beds of the Claiborne formation by the great numbers of shells of *Ostrea sellæformis* Con. which it holds. These shells are found more abundantly in the hard, sandy ledges which occur at intervals of a few feet through the whole thickness of these beds. This part of the Claiborne formation, contrary to the experience of Professor Winchell,[2] we find to be the most widely distributed of any. We have identified it within two miles of Nicholson's Store in Choctaw County; at several localities on Souilpa Creek, in the same county; at Coffeeville; near Old Clarkesville; on Stave Creek; and near Lisbon Landing, in Clarke County; at Claiborne; near Monroeville; and at several places on Limestone Creek, in eastern Monroe County. It is described by Professor Hilgard[3] as occurring on Falling Creek, near Quitman, and on Suanlovey Creek, west of Enterprise, in Clarke County, in Mississippi, and it has been observed by Mr. Johnson in Wahtubba Cut, 5 miles

[1] Rep. on Geol. and Agric. of Mississippi, pp. 118, 119, 121, 122, 123, 124, 125, 1860.
[2] Proc. Am. Ass. Adv. Sci., Vol. X, Part II, p. 86, 1856.
[3] Rep. on Geol. and Agric. of Mississippi, pp. 126, 127, 1860.

southwest of Enterprise, Miss. We have not yet followed it further east than Evergreen, Conecuh County, though we have good reason for believing that it occurs near Elba, in Coffee County, and probably still further eastward. Below these *Ostrea sellæformis* beds we find at Claiborne and at Lisbon some 50 feet or more of sandy and clayey beds, in many cases strongly glauconitic, and holding a great number as well as a great variety of well preserved fossils.

Such are a few of the most obvious characters of the beds which we here wish to include in our Claiborne formation. The precise details of the structure and composition of these beds may be gathered from the sections which follow.

The rocks of the Claiborne formation proper occur at Claiborne, Gosport, and Rattlesnake Bluff, on the Alabama River, and at many other localities in that vicinity. They also occur on the Tombigbee River at Baker's Bluff (a short distance north of Saint Stephens) at Coffeeville and at very many points away from the rivers in Monroe, Clarke, Washington, and Choctaw Counties. We are at this time concerned only with the occurrences along the two rivers.

(*a*) The bluff at Claiborne affords one of the best exposures of the rocks of the Claiborne formation, as well as of part of the overlying Jackson strata, and we have therefore been at considerable pains to get a correct and detailed section of this celebrated bluff. It will be understood by every field geologist that no two observers will ever make the same grouping of the strata in a detailed section, and for this reason sections of the same bluff by different observers will often seem to be at variance with one another. The same bed, moreover, in different parts of a long bluff will often vary considerably in thickness and in other characteristics. Thus, along the road leading to the ferry at Claiborne, the ferruginous sands are less than ten feet in thickness and are overlaid with laminated clays holding leaf impressions, but these clays thin out rapidly going down the river and disappear altogether in less than a quarter of a mile from the ferry road. Our section, therefore, does not profess to be a section at one point only of the long Claiborne bluff, but we have examined and given the details of the different beds wherever they are most clearly exposed, from below the lower landing up to the ferry.

In this part of the State the Alabama River depression exhibits at least two well defined terraces; the upper one, from one hundred and seventy-five to two hundred feet above low water mark; the lower, from thirty to fifty feet above the same mark. The upper terrace is formed by the Tertiary rocks, which are, however, covered by thirty to forty feet of the sands and pebbles and loam of the drift. Upon this terrace, about a mile wide, the town of Claiborne stands. The second or lower terrace, in great measure above overflow, except in extremely high water, is formed of ancient river deposits to which the name "second bottom" has been given. Opposite Claiborne the second bottom is some three

miles wide, and the river pursues its winding course in a channel cut into these second bottom deposits, impinging first against one side of the bordering Tertiary bluffs, whence it is deflected across the wide second bottom to strike then the opposite border. At Claiborne the river flows at the base of the southern Tertiary border of its ancient plain; next it turns across this plain and strikes the northern Tertiary bluff at Gosport; it is then deflected to strike the southern margin again at Rattlesnake Bluff.

The feature of the Claiborne bluff which first attracts the eye of the observer from a distance is the existence of nearly horizontal parallel stripes or bands which mark the limits of the different materials that make up the bluff. These bands, which are pretty well brought out in the views, are marked off approximately in the second vertical column of Plate XIII, Fig. 3, p. 147, and, if we neglect the minor details, they may be described as follows:

Section of the Claiborne Bluff, Alabama River.

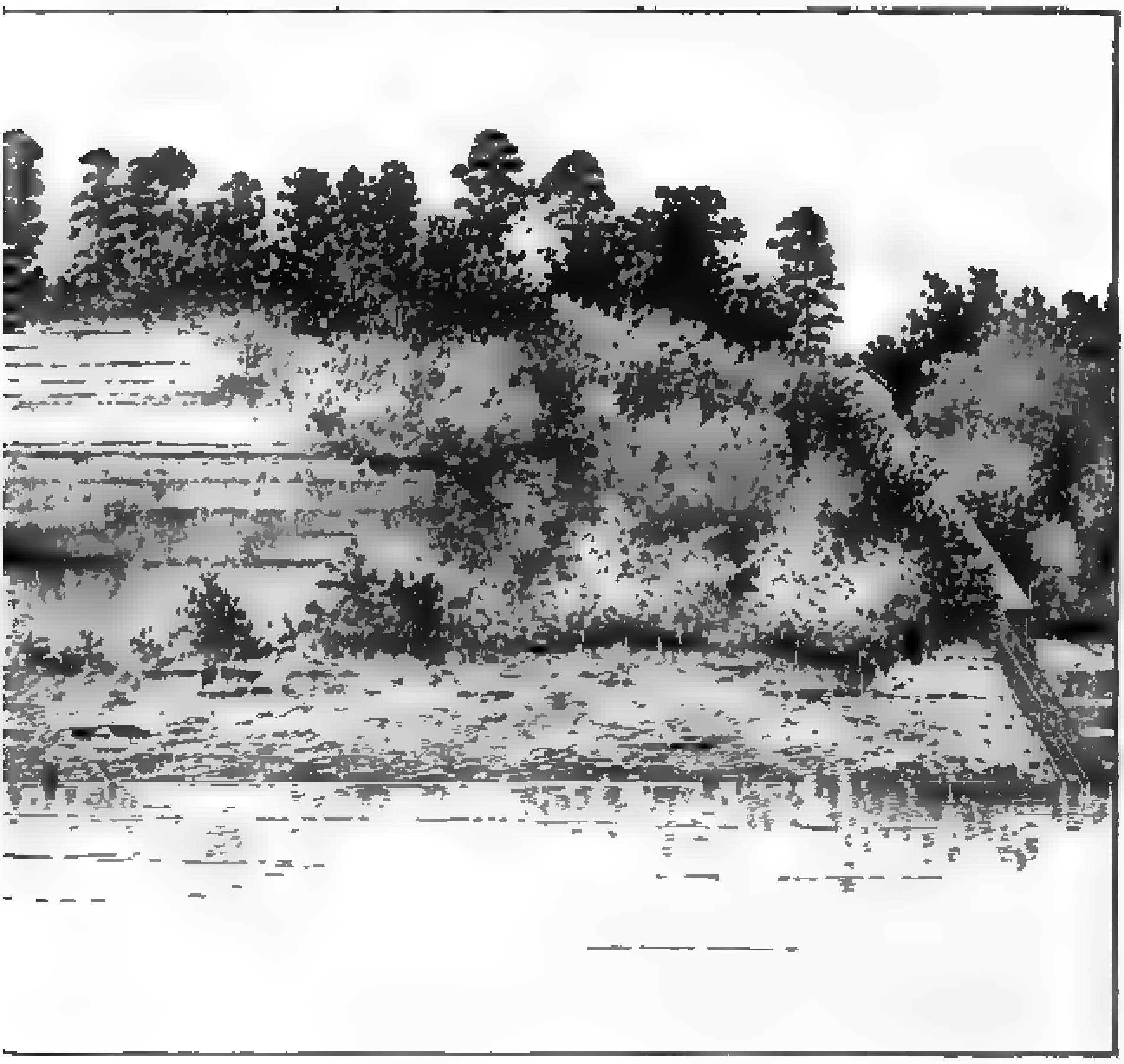
1. A bed of very variable thickness, consisting of sand, pebbles, and red loam, which forms the surface over a great part of the State. The average thickness of this bed along the bluff may be put at ....35 to 40 feet.
2. A band of White Limestone containing glauconite grains, forming vertical faces usually striped by thin projecting ledges ....about 45 feet.
3. A band showing two very distinct parts, viz, an upper part, a bed holding great numbers of *Scutella Lyelli*, 3 feet thick; and a lower part, 6 feet thick, of coarse, ferruginous sands which are indurated at the base and form a very marked projecting ledge..............9 feet
4. A band of very uniform appearance of reddish yellow or buff color, consisting of a mass of shells embedded in red sand. This is the celebrated Claiborne sand. It weathers very smoothly and is less projecting than the ledges above and below it ....15 to 17 feet
5. A band of light gray, calcareous clay with a few sandy stripes and indurated ledges ....25 to 28 feet.

All these beds make up the nearly vertical part of the bluff near and between the two landings. Below these to the river level the slope is almost entirely covered by the loose fragments rolled down from above, so that the underlying stratified rocks are discovered only where these loose materials have been removed. Between the upper landing and the ferry these lower strata of the bluff are more clearly exposed to view.

6. A band of light yellowish gray, calcareous sand, striped with a number of hard ledges of similar sandy material. This band is a very prominent part of the bluff, but is in many places, as above stated, much obscured by the fragments of the other beds which have rolled down from above..............about 35 feet.
7. A band of dark, bluish green color, consisting of clayey sands and clays passing downwards into a greensand bed 6 to 8 feet thick, which appears, however, above water only above the upper landing..............about 12 feet.

The upper part of this band, at the lower landing, appears only two or three feet above the low water mark, and it is consequently best seen farther up the river. Between the two landings these beds, where they


1
2
3
4
5



b. Fossiliferous sands. a. *Ostrea sellæformis* beds.

LOWER LANDINGS, ALABAMA RIVER

are above water, are generally covered with débris. The second of the bands above named is the lower part of the Zeuglodon bearing bed of this part of the State, which has generally been considered as of Jackson age. The third band is also probably a part of the Jackson limestone, but we are not sure that some of it, especially the lower five or six feet, should not be placed with the Claiborne division. At any rate the line between the Claiborne and the Jackson falls somewhere in this band (Plate I, p. 3, and Plate III, p. 29).

Given more in detail, the section of the Claiborne bluff is as follows:

Detailed section of Claiborne Bluff, Alabama River. (*Plate XIII, Fig.* 3, *p.* 147.)

1. Drift deposits, consisting of sand, pebbles, and red loam of variable thickness........35 to 40 feet.
2. Argillaceous, white limestone, with grains of glauconite, very few fossils..45 feet.
3. Scutella bed; light colored, calcareous materials, holding great numbers of *Scutella Lyelli* Con........3 feet.
4. Coarse, ferruginous sand, with glauconite, fossiliferous, passing below into more calcareous material, which is indurated and projects from face of bluff....6 feet.
5. Ferruginous sand, holding vast numbers of comminuted as well as well preserved shells. Near the center of this there are, in places, thin bands of lignite, and along the ferry road the upper part of it is composed of laminated gray clays filled with leaf impressions. This is the source of the celebrated Claiborne fossils, and we shall call it the Claiborne Fossiliferous Sand. In many parts of Monroe and Clarke Counties, where this bed is more protected, the material in which the shells are embedded is seen to be a greensand, while at the Claiborne bluff and vicinity, and at a bluff just above Saint Stephens, it is completely oxidized into a red, ferruginous sand. Thickness about Claiborne............15 to 17 feet.
6. Bluish green, glauconitic, sandy marl, with *Ostrea sellæformis*, usually somewhat indurated above, and forming a hard projecting ledge...............3 to 4 feet.
7. Calcareous clay or clayey marl, of gray color when dry, but blue when wet. It contains a few badly preserved chalky fossils, *Bulla* and small *Turritellas*. This bed becomes sandier below, as well as glauconitic and highly fossiliferous, the principal shells being *Ostrea sellæformis* and a few *Pectens*. The clayey and sandy parts, together........about 18 feet.
8. Light gray, calcareous clay, similar to the upper part of the preceding bed, with hard sandy ledges at top and bottom........7 feet.
9. Light yellowish gray, calcareous sands, with *Ostrea sellæformis* and *Pectens*; the lower half indurated and full of the molds or casts of univalve shells......5 feet.
10. Light yellowish gray, calcareous sands like those which make the upper half of bed No. 9. This bed has several hard projecting ledges of the same sandy material and contains a number of fossils: *Ostrea sellæformis*, fragments of *Scutella Lyelli*, *Scalpellum Eocense* Myer, *Pecten Deshayesii* Lea, &c. The sandy parts of this bed are loose, crumbling easily between the fingers. There are thin beds of more clayey texture, one of which, about the center of the stratum, holds a number of irregularly shaped, concretionary masses of clay. Near the base are one or two indurated ledges of glauconitic sand and shells of *Ostrea sellæformis*..27 feet.
11. Layer of comminuted shells of *Ostrea sellæformis*, together with perfect shells of some other species embedded in glauconite or greensand................3 feet.
12. Dark bluish black, sandy clay........2 feet.
13. Bluish green, clayey sands with few fossils in the upper part, but becoming more clayey below and highly fossiliferous; *Venericardia planicosta*, *V. rotunda*, *Nucula magnifica*, *Arca rhomboidella*, *Ostrea sellæformis*, *Voluta Sayana*, *Turritella lineata*, *T. bellifera* Aldrich, besides species of *Natica*, *Corbula*, *Cytherea*, *Lucina*, &c. This bed averages 10 feet or more in thickness.

14. Dark green, sandy marl, glauconitic; grayish above, bluish below. This bed is sometimes badly weathered and of more brownish color. It holds a number of fossils, among which the most noticeable are a peculiar small form of *Venericardia planicosta* Lam. and large *Turritella Mortoni* Con. This bed, which is the lowest at Claiborne, may be seen between the upper landing and the ferry, and its exposure is from six to eight feet, according to the stage of the water.

(*b*) A few miles above Claiborne, near Lisbon Landing, we find the continuation of the Claiborne beds down to the top of the Buhrstone, and there is no doubt as to the geologic horizon of the Lisbon section, since the two lowermost beds of the Claiborne section appear at the top of the Lisbon bluff, the peculiar association of the shells making the identification easy and certain. In the following full section at Lisbon the bracketed numbers show the relations of the Lisbon beds to those of Claiborne, as indicated in Plate XIII.

Section at Lisbon Bluff, Alabama River.

1. Drift and loam ....20 feet.
2. [13] Brown, sandy clays, difficult to describe more closely, as they are badly weathered and contain very few fossils..10 feet.
3. [14] Dark brown, sandy clays, badly weathered, highly fossiliferous, containing the same shells as beds Nos. 13 and 14 at Claiborne, viz, the peculiar small variety of *Venericardia planicosta* Lam., large *Turritella Mortoni* Con., *Arca rhomboidella* Lea, *Lucina compressa* Lea, *Nucula magnifica* Con., *Turritella bellifera* (Aldrich), &c. This bed becomes more sandy below ....8 to 12 feet.
4. [15] Hard projecting sandy ledge.......................................8 inches.
5. [16] Calcareous, clayey sands, light yellow when wet, nearly white when dry, glauconitic, forming smooth vertical bluff ....6 to 8 feet.
6. [17] Coarse grained, sandy, glauconitic bed with comminuted shells and many finely preserved shells of uncommon occurrence ....3 feet.
7. [18] Light yellow, glauconitic sands capped with hard ledge ....15 feet.
8. [19] Blue, glauconitic sands, probably the same as No. 7 above, but less completely oxidized, lowest of Claiborne strata ....5 feet.
9. Bluish black clay, 8 feet actually seen, below which, to the water, 5 feet, all the strata are covered by fragments of the concretionary sandstone described below.

In the clay immediately below the glauconitic sands, No. 8, concretionary masses are formed, which resemble a tangled mass of roots or branches, exposed in high relief upon a plate or block of sandstone. These root-like concretions lie strewn upon the lower strata of the bluffs about Lisbon, and seem to be somewhat characteristic of this particular horizon, which we place at the very summit of the Buhrstone division, the Claiborne proper extending to and including No. 8 [19] of the above section.

The combined sections of the Claiborne Bluff and the Lisbon Bluff show the whole of the Claiborne formation, which, according to our division, extends from the White Limestone down to the top of the Buhrstone and includes about 140 feet of strata, of which 106 are to be seen in place at Claiborne, while the rest may be seen a few miles above Claiborne at Lisbon.

The fossiliferous sands (No. 5 of Claiborne section) have furnished the greater part of the beautiful Claiborne shells. The uppermost five

or six feet of this bed are made up chiefly of the shells of *Cytherea æquorea* Con., *Pectunculus Broderipii* Lea, and *Crassatella alta* Con., 90 per cent. of the shells belonging to the first named species. The two feet next below contain not only many of the Cythereas but great numbers of other shells also, the most prominent of which are *Turritella lineata* Lea, *Rostellaria velata* Con., *Crepidula lirata* Con., *Turbinella pyruloides* Con., *Voluta Defranckii* Lea, *Monoceros armigerus* Con., *Melongena alveata* Con., *Ancillaria subglobosa* Con., &c.[1]

The strata below the Claiborne sands are much less fossiliferous and more sandy, *Ostrea sellæformis* being by far the most abundant shell down to the black clay stratum near the base of the bluff. The greensand beds at the base of the Claiborne bluff and at the top of the Lisbon bluff contain many of the rarer forms. The marl bed No. 6 of the Lisbon section promises to yield a rich harvest of novelties.

The collocated sections on Plate XIII give the details of the preceding drawn to scale. For the sake of comparison we give on the same sheet the sections of Professor Tuomey[2] and of C. S. Hale.[3] Hale's No. 3 corresponds with our Nos. 14 and 15. His No. 4 and Tuomey's bed *b* are represented by our Nos. 12 and 13 and part perhaps of 11. Hale's beds 5 and 6 and Tuomey's *c* are our numbers 6 to 11, inclusive. The correspondence of the rest of the sections is easily seen.

Some of the more important exposures of the Claiborne beds elsewhere are the following:

(*c*) A few miles below Claiborne, at Gosport landing, there is substantially the same section as that at Claiborne.

(*d*) At Rattlesnake Bluff, below Gosport, there is the following section (see Plate XII, Fig. 4, p. 143):

Section at Rattlesnake Bluff, Alabama River.

1. Ferruginous sands, becoming more calcareous below and terminating with a hard ledge .... 6 feet.
2. Claiborne fossiliferous sands .... 10 to 12 feet.
3. Calcareous clay or hard clay marl, with an indurated ledge in the middle .... 6 feet.
4. Clay marl, with *Ostrea sellæformis*, with four or five hard, projecting ledges, about .... 10 feet.
5. Greensand, indurated at top but softer below, extending down to the water, about .... 2 feet.

(*e*) On the Tombigbee River, half a mile above Saint Stephens, there is a good exposure of the Claiborne sands, with some 10 to 12 feet of the next underlying beds, already given above in a section illustrating the White Limestone. (See Plate XII, Fig. 3, p. 143.)

[1] Aware of the fact that most of these shells have synonyms, we have in most cases given our authority for the names used by us, leaving the question of priority to be decided hereafter.

[2] First Bien. Rep. Geol. Ala., p. 153, 1850.

[3] Geology of South Alabama, Am. Jour. Sci., 2d ser., Vol. VI, p. 354, Nov., 1848.

(*f*) Still farther up the river, at Coffeeville landing, the *Ostrea sellæformis* beds of the Claiborne profile form the river bluff, as may be seen from the following:

Section at Coffeeville Landing, Tombigbee River. (*Plate XIII, Fig. 4, p. 147.*)

1. Light yellowish sands, with *Ostrea sellæformis*, partly indurated, forming sandy ledge .... 3 feet.
2. Loose, yellowish, calcareous sands, with *Ostrea sellæformis*, indurated, sandy ledge at base .... 6 feet.
3. Loose, yellowish gray, calcareous sands, highly fossiliferous, especially in lower part; *Ostrea sellæformis* the principal form; separated from next bed by sandy ledge .... 10 feet.
4. Bluish, sandy clay or clayey sand, with *Ostrea sellæformis* and a flabellum; in two parts, separated by a hard ledge, the upper part 8 feet, the lower 3 or 4 feet, in all .... 12 feet.
5. A bed of glauconitic sand filled with shell fragments and perfect shells: *Ostrea sellæformis* Con., *Crassatella alta* Con., a flabellum, *Venericardia rotunda* Lea, *Corbula Murchisoni* Lea, *Pecten Deshayesi* Lea, *Arca rhomboidella* Lea, *Nucula magnifica* Con., &c .... 2 to 3 feet.
6. Dark bluish clays, nearly black, non-fossiliferous, breaking into cuboidal blocks .... 2 feet.
7. Dark greenish, clayey sand, like that near the base of the Claiborne Bluff, about 5 feet showing above the water.

The accompanying view of Coffeeville Landing (Plate IV) shows well the general character of the lower Claiborne beds. The lowest wood piles rest upon the black clays, No. 6, equivalent to No. 12 of the Claiborne Bluff section. The main fossil bearing bed, No. 5, is immediately over this, between it and the first (lowest) of the projecting ledges seen in the plate.

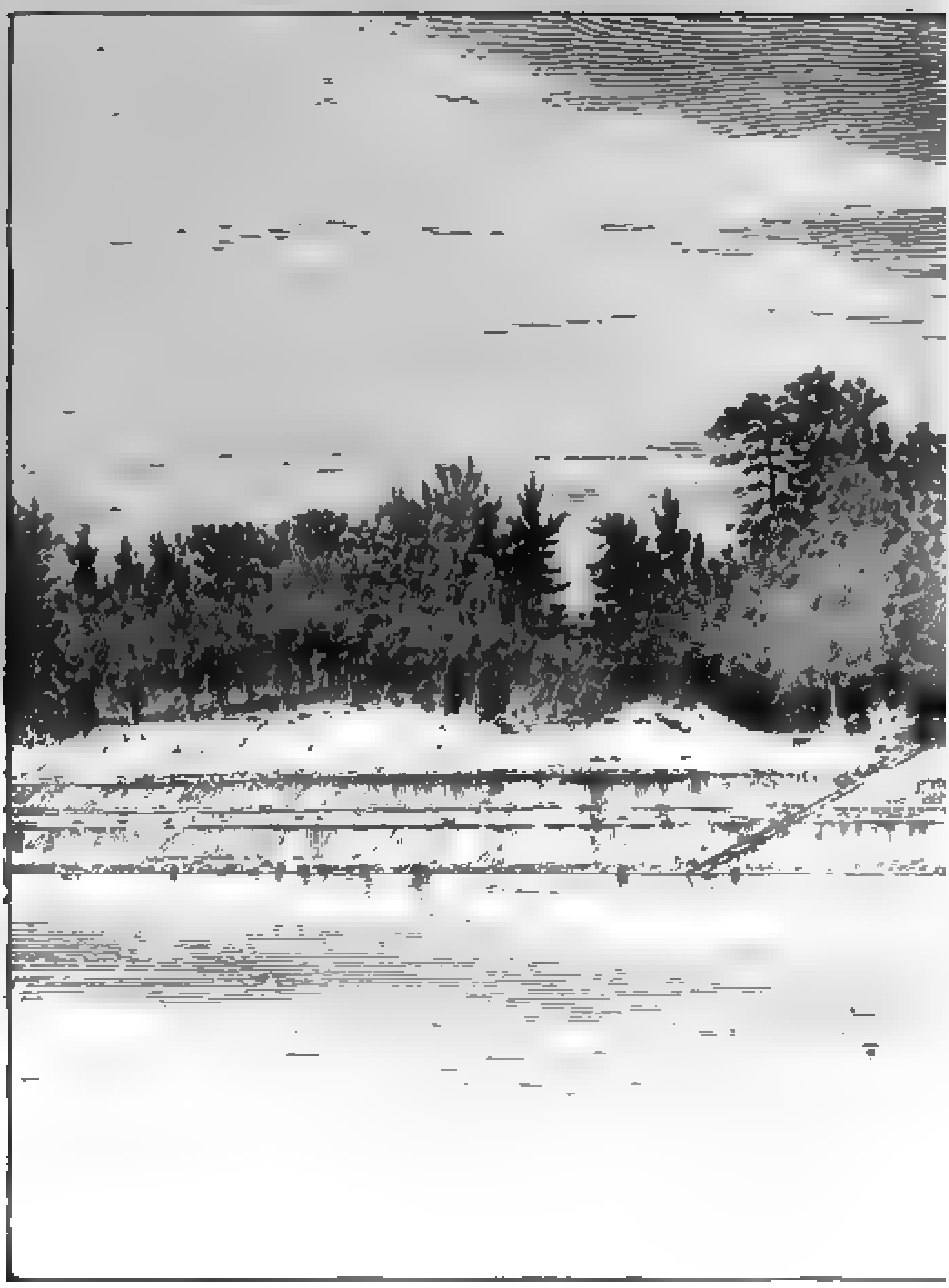
Hale states[1] that his bed No. 4 occurs also at Coffeeville with the same fossiliferous characters, and a comparison of the Claiborne Bluff section with the above shows very clearly the correspondence of the two. The bed No. 5 above is identical with No. 11 at Claiborne, except that it holds *Crassatella alta* and a few forms which we have not seen at the same horizon at Claiborne; but the underlying black clay (No. 6) is equivalent to No. 12, and the overlying bluish and yellowish, fossiliferous sands (Nos. 1–4) are identical with Nos. 9 and 10 of our Claiborne Bluff section. These relations are shown in the sections, Plates XII and XIII.

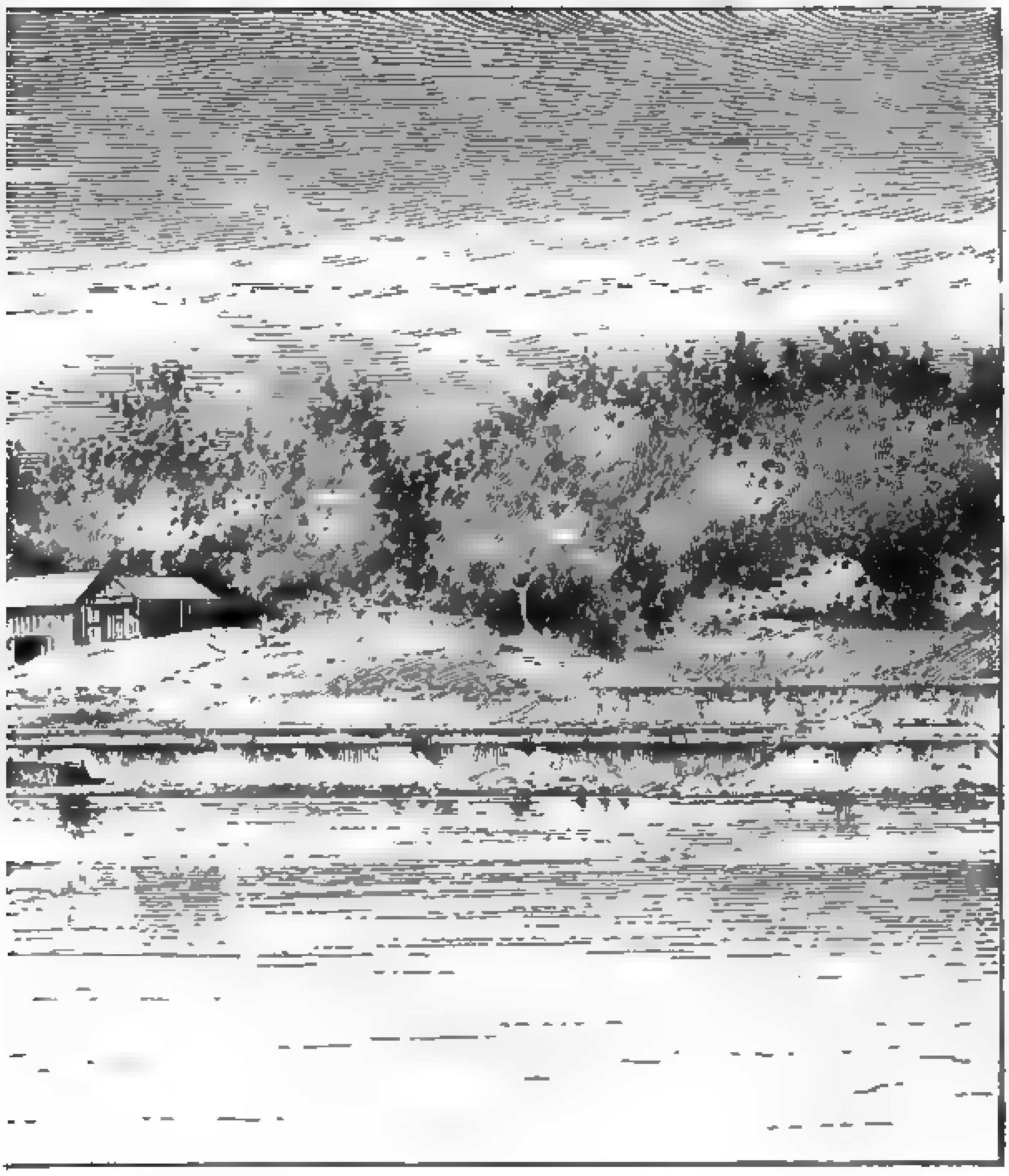
There are no other exposures of the Claiborne beds along the two rivers, but in Washington, Clarke, and Monroe Counties we have recently (summer of 1885) visited a number of localities where the Claiborne beds are to be seen often in contact with the overlying White Limestone.

(*g*) Thus, north of Bladen Springs, on descending the hill towards Souilpa Creek, yellowish sands, with *Ostrea sellæformis*, the counterpart of our Nos. 9 and 10, are passed over along the road, while above them, near the top of the hill, is a fossiliferous bed holding forms common both to the Claiborne sands and to the marls at the base of the Claiborne Bluff.

[1]Am. Jour. Sci., 2d ser., Vol. VI, Nov., 1848.

U. S. GEOLOGICAL SURVEY





NO. 3, TUMAHCHEE RIVER

(*h*) At the Barryton mill on Oaktuppah Creek, three miles northeast of the village of Barryton, there is a bed of greensand filled with broken and perfect shells of *Ostrea sellæformis*, identical with No. 11 of our Claiborne Bluff section, and above it, as at Claiborne, a series of bluish and yellowish sands, with *Ostrea sellæformis*.

(*i*) About two miles northward from this mill the Claiborne fossiliferous sands occur, and at Womack's Hill, still further northward, the White Limestone caps the hill.

(*j*) The yellow sands, with *Ostrea sellæformis*, are also seen at a mill on the headwaters of Oaktuppah Creek, in the western part of Choctaw County, Sec. 8, T. 11 N., R. 4 W., and again within two miles of Nicholson's Store, on Billy's Creek, where they are exposed at the base of a hill capped with the White Limestone.

(*k*) Thirteen miles west of Bladen Springs, D. W. Langdon, jr., of the Geological Survey of Alabama, saw in 1884 an outcrop of greenish, argillaceous sand, weathering red and containing a number of shells peculiar to the Claiborne sands, such as *Crepidula lirata*, *Corbula Alabamensis* Lea, and others commonly found in the Claiborne sand but not peculiar to it. This bed also was beneath the White Limestone.

(*l*) In the northern part of Washington County I saw, in 1882, an outcrop of marl containing *Turritella Mortoni* Con., *Ostrea sellæformis* Con., *Voluta Sayana* Con., &c., on Dry Creek, Sec. 6, T. 8, R. 2 W.

(*m*) In Clarke County, near the site of Old Clarkesville, in Sec. 23, T. 9 N., R. 2 E., there is seen in the bed of a branch a greensand containing all the peculiar shells of the Claiborne fossiliferous sands, and on the hills above White Limestone containing bones of Zeuglodon.

(*n*) In Sec. 18, T. 9 N., R. 3 E., the same beds occur, and in the same relations to the White Limestone.

(*o*) On Stave Creek, in Secs. 8 and 9 of T. 7 N., R. 2 E., and in other localities in the immediate vicinity, the Claiborne sands, with all their easily recognizable and unmistakable shells, are at the water level in the creek banks, while the White Limestone outcrops on the hillsides hard by, with orbitoidal limestone on the summits.

(*p*) D. W. Langdon, in 1884, observed the Claiborne sands also nine and a half miles south of west of Grove Hill and fifteen miles east of Coffeeville, in both cases underlying the White Limestone. The locality on Stave Creek was visited by Prof. A. Winchell[1] and the localities near old Clarkesville were seen by Professor Tuomey[2] and by Professor Winchell[3] also.

(*q*) In Monroe County the yellow sands, with *Ostrea sellæformis*, occur in sections 25 and 34 of T. 7 N., R. 8 E., and in sections 19 and 30 of T. 7 N., R. 9 E., partly on the land of Mr. T. A. Rumbly.

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[1] Proc. Am. Assoc. Adv. Sci., Vol. X, Part II, pp. 84, 85, 1856.

[2] First Bien. Rep. Geol. Alabama, p. 149.

[3] Proc. Am. Assoc. Adv. Sci., Vol. X, Part II, p. 86, 1856.

(*r*) In Sec. 2, T. 7 N., R. 7 E., occur the yellow sands, with *Ostrea sellæformis*, as at Rumbly's, and in Sec. 12, T. 7 N., R. 7 E., the Claiborne greensand, with all the characteristic shells, occurs in the branches of the creeks, while the White Limestone occupies the summits of the hills.

Our observations correct a statement of Professor Winchell[1] that the calcareous beds underlying the Claiborne sands are not seen elsewhere. These beds are now known to occur from the western part of Choctaw to the Sepulga River, in Conecuh County, and probably still farther eastward.[2]

Other occurrences of the Claiborne beds, observed in 1886, will be found described below in the chapter on undulations &c.

§ 3. THE BUHRSTONE.

The fossils of this subdivision, as has already been suggested by Dr. Hilgard, do not appear to differ essentially from those of the calcareous Claiborne strata above described, yet the lithological character is so entirely different as fully to justify the division here made.

The rocks of the Buhrstone formation in Alabama, as well as in Mississippi, consist of aluminous and silicious materials, partly glauconitic, and in places interstratified with thin beds of greensand. The chief varieties of these rocks, in the order of their relative abundance, are the following:

1. Gray, aluminous sandstone, often glauconitic, with numerous galls or concretions of pure whitish clay and traversed throughout with streaks of yellowish, hydrated oxide of iron. In this rock are occasionally found impressions of shells. In the upper part of the formation, upon the surfaces of this sandstone irregularly branching, cylindrical elevations of slightly harder texture, but apparently of similar composition, are sometimes seen. These ridges have in some cases the appearance of being organic remains (fucoidal), but are more probably concretionary. These are best seen at Lisbon Landing on the Alabama River, and west of Bladen Springs, in Choctaw County, and at other points along the southern line of this formation.

2. Indurated, white clay, forming a rock, which is, however, quite light and easily broken. This indurated clay has joint planes approximately at right angles to one another, the planes of separation being mostly stained red or yellow with hydrated ferric oxide. Fragments of this claystone worn into rounded pebbles are of common occurrence in most of the creeks and branches flowing through the Buhrstone hills, both in Alabama and in Mississippi. The claystones are often silicious.

3. Hard, coarse grained, glauconitic sandstone.

4. Hard, yellowish, silicious, or aluminous sandstone, streaked with a darker shade of yellow.

5. A white, silicious rock, almost a quartzite, varied by spots of leaden gray color. This rock has often furnished the material for Indian lance and arrow heads. It occurs near the base of the series, associated with a hard, silicious sandstone.

The prevailing color of the rocks of this formation is light gray, often nearly white, and, on account of their hardness and resistance to decay.

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[1] Proc. Am. Assoc. Adv. Sci., Vol. X, Part II, page 86, 1856.

[2] D. W. Langdon, jr., has also traced these sandy *Ostrea sellæformis* beds into Mississippi, as far as Suanlovey Creek, near Garlandsville, in Newton County, a locality already recorded by Dr. Hilgard. See paper "On the Tertiaries of Mississippi and Alabama," in Am. Jour. Sci., 3d ser., Vol. XXXI, Mar., 1886. See, also, pp. 25-33 and foot-notes.

the country which they make is very broken and rugged. The high and often precipitous hills of the Buhrstone are usually called *mountains* in Clarke, Monroe, and Choctaw Counties, in this State, and in northeastern Clarke, Lauderdale, Newton, and Neshoba Counties, in Mississippi. The soil, where it is derived from these rocks, is, of course, poor, and mostly timbered with long leaf pine, and the country is generally very sparsely settled.

It is impossible as yet to give with absolute certainty the thickness of this division of the Tertiary. During the summer of 1885, I measured with the aneroid barometer at one locality, near McCarthy's Ferry, in Choctaw County, 270 feet of Buhrstone rocks, and, as this section did not include the uppermost beds of the formation, we are safe in placing 300 feet as the minimum thickness. I am strongly inclined to the opinion that the real thickness, in some cases, will rise to 400 feet. In the section we give the lower limit, 300 feet.

In general, the uppermost beds (fifteen to twenty feet) are composed of joint clays, which, when indurated, form tolerably firm rocks. Near the base of the formation similar clays or claystones are usually seen. In many places, there is a bed several feet in thickness of a hard, silicious, or flinty sandstone, almost a quartzite, just at the base of the Buhrstone. I have noticed this rock a few miles north of Bladen Springs, also near McCarthy's Ferry, and south of Pushmataha, in Choctaw County. In Choctaw and Clarke Counties it is not unusual to find spear or arrow heads made of this material, which is easily recognized. The great bulk of the Buhrstone, as already said above, consists of aluminous sandstones.

Inasmuch as we have not yet been able to point out any characteristic distinction, based upon organic remains, between the Buhrstone and the Lignitic, we have thought it best to draw the line between them upon lithologic grounds, and our justification in this course is found in the following considerations: In the strata which we have called Lignitic, the material, as compared with that of the Buhrstone, is more sandy and calcareous and at the same time more fossiliferous. The shells in many cases are decayed and the calcareous matter of the same often appears to have been leached out and diffused through the surrounding sands, occasionally cementing them together and forming calcareous sandstone. These sandstone beds always show a tendency to weather into rounded, bowlder-like masses, which project from the faces of the bluffs or, broken off, roll down, forming a talus. When broken open, these bowlders usually show a nucleus of thoroughly decayed shells or of ferruginous, lignitic matter.

A ledge of calcareous sandstone of this kind is found about twenty or thirty feet below the lowermost of the aluminous rocks, which we consider as characteristic of the Buhrstone, and similar calcareous sandstones weathering into bowlders occur at intervals throughout the underlying lignitic strata.

The aluminous rocks we assign to the Buhrstone, while the sandy rocks, with the intercalated beds of calcareous matter, we place with the Lignitic.

This division based upon lithologic characters can be consistently carried out in Alabama, at least in the region contiguous to the two rivers, since the indurated clays and aluminous sandstones of the Buhrstone are in general easily distinguished from any of the other strata of the Tertiary formation. None of the beds of the underlying Lignitic have even a remote resemblance to the Buhrstone rocks, except certain indurated clays which overlie the *Gryphæa thirsæ* beds in the Grampian Hills of Wilcox County and their prolongation into Butler County. Even in this case the distinction between the two can readily be discovered, as the indurated clays of the Lignitic are, in some of the beds, quite full of shell casts, principally Turritellas and Cythereas, and the material itself, upon close examination, does not so strongly resemble the Buhrstone as upon first sight appears. Then the circumstances that these lignitic claystones lie over 300 feet below the Buhrstone, are by no means so thick, and are in most, if not all, cases in immediate contact with the *Gryphæa thirsæ* beds greatly diminish the chance of any confusion between the two series.

On the Alabama River the uppermost of the Buhrstone beds are well exposed at Lisbon Landing, and the lowermost, a short distance above Hamilton's, whence they extend across Clarke County westward or northwestward to White Bluff and McCarthy's Ferry and thence in a northwesterly direction across Choctaw County, just south of Butler. On the eastern side of the Alabama River they appear in the hills south of Bell's Landing, and across Monroe County north of Kempsville and south of Turnbull, turning a little to the northward in the eastern part of the county. To the eastward they may be seen again near Ozark, in Dale County, and near Abbeville, in Henry County.

In general we have not attempted in the following sections to give the exact sequence of the different materials which form the Buhrstone beds. In most cases they are merely alternations of indurated clays, with aluminous sandstones of varying degrees of hardness. While in the extremes of pure clay and almost pure quartz the materials of this formation differ widely, the formation as a whole leaves upon the mind of the observer a lively impression of the uniformity in the lithological structure and general appearance of its constituent strata.

Although the best natural sections of the Buhrstone are perhaps to be found in the hills away from the rivers, we shall here describe only the exposures along the banks or in the immediate vicinity of the two water courses. The sections on the Alabama River are as follows:

(*a*) *Section at Lisbon Landing, Alabama River.* (*Plate XIV, Fig. 1, p. 151.*)

1. Yellowish, sandy marl, lowermost of the Claiborne beds .... 20 feet.
2. Bluish black clay, massive, jointed or breaking into cuboidal blocks, 8 feet seen, but to the water's edge ....about 15 to 20 feet.

Immediately beneath the sands which form the lowermost beds of the Claiborne formation in this section concretions are formed which resemble a mass of tangled and matted roots. Blocks of sandstone with these concretions cover all the lower part of the section at Lisbon and they seem to be more or less characteristic of the uppermost beds of the Buhrstone.

(*b*) At Hamilton's Landing, 6 miles above Lisbon, is an exposure of 75 to 80 feet of light colored, indurated clays or clayey sandstones with two or three indurated, projecting ledges, all characteristic Buhrstone rocks. (See Plate XIV, Fig. 2, p. 151.)

The positions of the outcrops of the Buhrstone rocks on the Tombigbee River present apparent anomalies which, at the time of our visit in 1883, we could not explain. The later observations, however, made by myself in 1885 have cleared up many of the obscurities, and the structure of the two counties of Clarke and Choctaw in its main features is pretty definitely made out. This will be set forth in detail in a forthcoming report of the Geological Survey of Alabama, while at this time we need only give the sections exposed on the river banks and in the immediate vicinity. As stated above, the regular line of outcrop of the Buhrstone rocks extends from near Hamilton's Landing, on the Alabama, across to the Tombigbee at White Bluff and McCarthy's Ferry. At both these localities we have very good sections of the lower beds of the formation.

(*c*) At White Bluff there is a clear exposure of these rocks in a cliff of about 115 feet. They are light colored, aluminous rocks, which, however, could not be closely examined because of the precipitous nature of the bluff. (See Plate XIV, Fig. 4, p. 151.)

(*d*) At McCarthy's Ferry the immediate bluff of the river is made of the clays which underlie the Buhrstone, but on the hills just back of the river we get a section of nearly 300 feet of Buhrstone rocks. (See Plate XIV, Fig. 3, p. 151.)

(*e*) Down the river from these localities the Buhrstone rocks dip beneath the surface, the overlying Claiborne beds forming the river banks, as at Coffeeville, &c., already mentioned, but just south of Coffeeville, at Hatchetigbee Bluff, the Buhrstone is again seen, and the lowermost beds at that, as shown in the section (see Plate XIV, Fig. 5, p. 151). The exposures at White Bluff and at the Hatchetigbee Bluff both show the contact of the light colored claystones with the underlying sandy clays &c. of the Lignitic, but at the former locality all except the uppermost 20 feet or so of the Lignitic are obscured by land slips and rubbish of all sorts. These sections will be given in detail under the next heading.

(*f*) Still farther down the Tombigbee River these rocks sink again below the surface, for at Saint Stephens, and just above, the Claiborne sands and the overlying White Limestone make the river bluffs, as before stated. At the Lower Salt Works, however, we have the Buhrstone

rising again to the surface, as described by Professor Tuomey.[1] During the summer of 1885 I ascertained that these rocks appear at the surface at an intermediate point, viz, near Jackson. The Lower Salt Works are situated near the center of T. 5 N., R. 2 E., and the rocks exposed along the road which ascends the hill just south of the works are as follows:

Section at the Lower Salt Works, Clarke County.

1. Orbitoidal limestone forming the upper part of the hill, thickness not determined.
2. Between the orbitoidal rock and the topmost bed of the continuous section below given there is a space in which the rocks are covered with soil, undetermined thickness.
3. Argillaceous White Limestone or clayey marl, with several indurated ledges of similar material ....about 18 to 20 feet.
4. Coarse grained, ferruginous sand, with harder ledge at base and above. This bed, as well as the harder portions, contains fossils, the most conspicuous of which are *Scutella Lyelli* and *Pecten perplanus*. This bed is strongly glauconitic near the base..about 9 feet.
5. Greenish clay passing at bottom into a ledge of hard claystone, the first of the Buhrstone formation ....3 feet.
6. Aluminous sandstones or indurated claystones of the usual Buhrstone character to the base of the hill..60 feet or more.

About half way down the hill there is a bed of greensand holding a good many fossils.

That which most strikes the observer in this section is the absence of the sands and marls of the Claiborne formation. The glauconitic sands with *Scutella Lyelli* and *Pecten perplanus*, supposed to be of Jackson age, immediately overlie the greenish clays of the Buhrstone, while at Claiborne the two are separated by at least 130 or 140 feet of other strata.

Professor Tuomey[1] called attention to the fact that the Buhrstone beds, after dipping beneath the surface in the upper part of Clarke County, appear again at the Lower Salt Works, the White Limestone and other calcareous strata occupying a basin in the Buhrstone formation. Our own observations on the river in 1883, and later in 1885 in the western part of Clarke County and in Choctaw County, have shown that the Buhrstone rocks appear at at least two intermediate points between the two limits observed by Professor Tuomey, viz, at Hatchetigbee and at Jackson.

§ 4. THE LIGNITIC.

All the strata lying between the Buhrstone and the Cretaceous, representing a thickness of 850 to 900 feet, have been classed by Dr. Hilgard under the two names of Lagrange (or Lignitic) and Flatwoods. Lately, Prof. Angelo Heilprin has proposed the name Eolignitic for both these divisions; but, since Dr. Hilgard had already used the name Lignitic in the same sense, that term has priority and must be retained.

[1] First Bien. Rep. Geol. Ala., p. 150, 1850.

The greater part of this subdivision is made up of laminated clays and laminated and cross bedded sands of a prevailing gray color, except immediately below the Buhrstone, where for 200 feet or more they are of dark brown, often purplish colors. With the above mentioned laminated clays and sands are interstratified several beds of lignite and several beds holding marine fossils and usually characterized by the presence of glauconite or greensand.

The lignite beds appear to be more numerous and thicker towards the west, and especially in Mississippi, while eastward of the Alabama River they become, as a rule, inconspicuous. Only one of these lignites, viz, that which appears at Coal Bluff, on the Alabama River, is of very considerable size, six or seven feet; they possess no very well marked characters by which they may be distinguished from one another; they are traced with difficulty across the country, since, being softer, they are more easily eroded than the associated rocks. On the other hand we have found the marine beds to retain their characteristic features to a remarkable degree: each has its peculiar association of fossils, most of them are also easily recognizable by lithologic and structural characters, and some of them may be followed with the greatest ease across at least three counties. These circumstances have led us to use the marine beds instead of the lignites for marking the different horizons of the Lignitic division, and provisionally we have thus used the seven following marls, each marking a well defined horizon and each presenting its easily recognized paleontologic character:

1. The Hatchetigbee marls.
2. The Wood's Bluff or Bashi marl.
3. The Bell's Landing series.
4. The Nanafalia or *Gryphæa thirsæ* marl.
5. The Matthews's Landing and Naheola marls.
6. The Black Bluff beds.
7. The Midway or Pine Barren beds.

Our account of the stratigraphy of the Lignitic division of the Alabama Tertiary will be more intelligible and more easily followed if we describe the strata in sections, each corresponding to and including one of the seven marl beds above enumerated.

(1) THE HATCHETIGBEE SERIES. (PLATE XV.)

In this we would include all the strata intervening between the base of the Buhrstone and the uppermost of the Wood's Bluff fossiliferous beds, aggregating about 170 to 175 feet, as may be seen by consulting the engraved sections of Plate XV, especially Fig. 1, p. 155.

By far the greater part of the beds here included are sandy clays or clayey sands of brownish gray colors, alternating with bands of dark brown or purple color, the whole forming a tolerably well marked and in most cases easily recognized group. Where these brown clays have been much exposed to the action of the atmosphere, and conse-

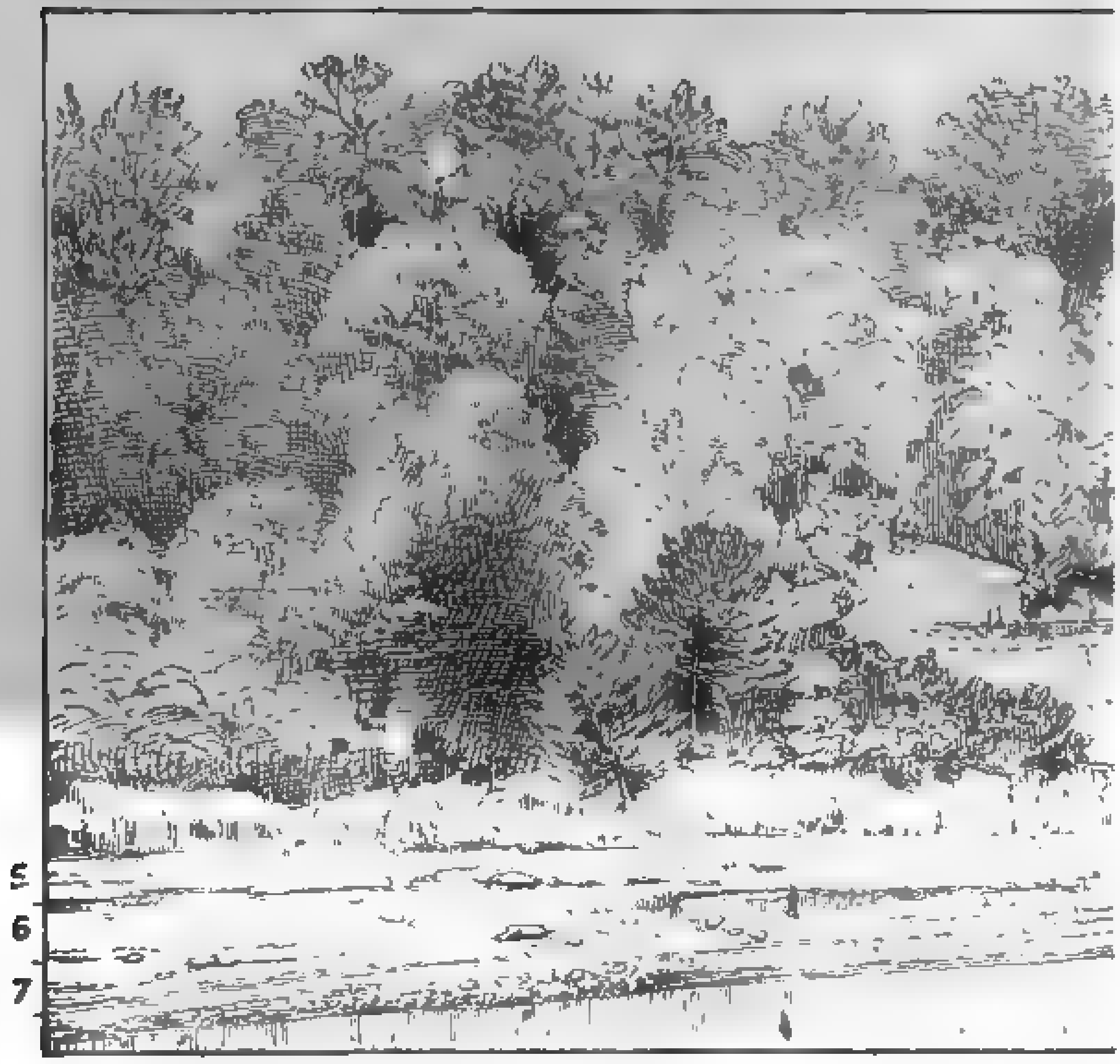
quently thoroughly leached, as occurs wherever they lie high up on the hills, they exhibit very much lighter and less characteristic colors. The best exposures of these beds are to be seen at the localities more particularly described below, and at one of them, White Bluff and vicinity, the whole series occurs in actual superposition, only about sixty-five feet of it being somewhat obscured by slides. The distinctively marine deposits of this series consist of three or four shell or marl beds, separated by non-fossiliferous sands and clays (Plate V).

(*a*) *Section at Hatchetigbee, Tombigbee River.* (*Plate XV, Fig. 2, p. 155.*)

1. Light colored, aluminous sandstones and indurated clays, forming a vertical escarpment back of the main bluff....20 to 30 feet.
   These light colored claystones we consider to be the lowermost of the Buhrstone formation, and all the underlying to be Lignitic.
2. Sandy clays of brown, yellowish, and reddish colors interstratified. These are dark blue when moist, but of lighter colors when dry....15 to 20 feet.
3. Heavy bedded, dark brown clays, somewhat like No. 2, but of darker color when dry....10 feet.
4. Yellowish, glauconitic marl....2 to 3 feet.
   This bed shows a tendency to form at intervals hard concretionary ledges, which on weathering break off and roll down the bluff and are piled in great numbers at its base.[1] Some of these bowlders have a nucleus of shells, which, however, are not usually very well preserved.
5. Purplish brown, sandy clays, in the middle of which is a projecting ledge of dark colored clays which are harder but break up into small prismatic fragments upon drying and on exposure to weather....15 feet.
6. Yellowish gray sands, striped with thin streaks of brown, sandy clay. These sands form, at intervals along the bluff, indurated, concretionary, rounded masses....5 to 6 feet.
7. Bluish brown, sandy, clay marl, containing many new forms of shells. The upper part more fossiliferous....5 to 6 feet.
8. Laminated, grayish sands, interstratified with thin beds of brown or black, lignitic clay. These sands form rounded, concretionary masses, which project from face of bluff....4 feet.
9. Heavy bedded, gray, sandy clays with streaks of brown clay....8 feet.
10. Reddish, sandy marl, highly fossiliferous, forming concretionary bowlders. Remarkable for the great numbers of *Venericardia planicosta* Lam., but containing also many other forms, such as *Athleta Tuomeyi* Con., and *Fusus pagodiformis* Heilprin....4 to 5 feet.
11. Dark gray to brown sandy clays to water....15 feet.

Beds No. 8 and 9 above form very conspicuous parts of the bluff, as they are striped with dark brown, nearly black, bands of clay and resemble strongly a part of the section at McCarthy's Bluff described below.

[1] Between our joint visit in 1883 and my second in 1885 the appearance of the bluff was very materially changed by a landslide. In 1883 we saw about six feet below the marl bed No. 4 another of very similar character, which I have now reason to think was a mere repetition of No. 4, since I was unable to make out two such beds in 1885. I have, therefore, given only one in the section, though convinced of the existence of two at the time of our first visit.



5. Lower part of purplish brown sandy clays. 6. Y

(The human figure stands upon the bed which we call the middle marl

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ellowish gray sands. 7 Bluish brown, sandy marl.

(References are to the sections on p. 43, and also to Fig. 2 of Plate XV.)

)F BLUFF, TOMBIGBEE RIVER

(*b*) At White Bluff, on the Tombigbee, as above stated, there is another exposure of the contact between the Buhrstone and the underlying Lignitic, which, however, includes in continuous exposure only the uppermost 25 feet of the latter formation. From the top of White Bluff down to the river level the distance is 275 feet by barometric measurements made at several different times. Of this, the uppermost 140 feet are shown in a clear perpendicular bluff and consist of 115 feet of the light colored claystones of the Buhrstone formation and 25 feet of sandy clays of the Lignitic. The strata composing the rest of the slope of White Bluff are so much obscured by landslides that it is impossible to make them out satisfactorily, but the lowermost 70 feet of the beds which make this slope are well exposed on the banks of Witch Creek and at Davis's Bluff, near by. Between these two parts of the section there are some 65 feet of strata not seen here, which include the Hatchetigbee marls &c. In proof of this, I found on the slope, a few feet below bed No. 3 of the accompanying section, a fragment of hardened, glauconitic marl with a few badly preserved fossils. The marl resembled that described in No. 4 of the Hatchetigbee section above. The fossils were, however, too obscure to be identified.

All this is shown in the following section and in Plate XV, Fig. 1, p. 155:

Section at White Bluff and Davis's Bluff, Tombigbee River.

1. Aluminous sandstones and claystones, of light color, forming a vertical bluff, the details of which it is impossible to examine closely, Buhrstone rocks....115 feet.
2. Grayish, sandy clays, with a layer about 18 inches in thickness at its base, containing fragments of lignitized stems and twigs........................20 feet.
3. Sandy clays, with a layer at bottom about 8 inches thick, consisting of alternating layers (one-fourth of an inch in thickness) of lignite and sand........5 feet.
4. Strata not seen, covered by landslides[1].................................65 feet.
5. Gray, sandy clays, striped with brownish purple bands of clay, containing few if any fossils, except that about 12 feet above the water there occurs a thin bed with a few fossil shells, and some 12 feet above this a single specimen of *Athleta Tuomeyi* was found sticking in the clay[2]...... ....70 feet.

White Bluff is in the southwestern part of Sec. 14, T. 11 N., R. 1 W., just below the mouth of Witch Creek.

(*c*) Above this, the river bends towards the west, and in the northwestern part of Sec. 6, T. 11 N., R. 1. W., at McCarthy's Ferry, the strata which make the lower part of the preceding section are again exposed, as may be seen from the following section:

Section at McCarthy's Ferry, Tombigbee River. (Plate XV, Fig. 3, p. 155.)

1. Sandy clays interlaminated with clays less sandy, all of light gray colors, but along the whole length of the bluff there are parallel bands of much darker clays, which make a very conspicuous marking ....50 to 55 feet.

[1] A fragment of glauconitic sandstone with fossils was picked up from the surface in this part of the section a few feet below the base of No. 3.

[2] These beds, as well as those included in No. 4, are covered by the débris of landslides at White Bluff, but they are well shown in the banks of Witch Creek, which washes the base of White Bluff, and at Davis's Bluff, half a mile above, where we get the lower 70 feet of the section (No. 5).

2. Laminated clays and sands, firm and compact at base, forming a projecting ledge which divides the bluff into two parts.......................4 to 5 feet.
3. Pyritous, sandy clays, with two or three bands of darker color; the sands are indurated in places, forming bowlder-like masses......................20 to 25 feet.

The dark bands which mark the bluff and which look at a distance like lignite beds are found upon closer inspection to consist of thin layers of dark bluish gray clays interbedded with thin streaks of gray sand. The whole 75 feet of this section appear to be barren of fossils.

At the base of the bluff lie great numbers of fragments of the silicious and aluminous rocks which characterize the Buhrstone formation and which have rolled down from the hills that rise a short distance back of the immediate bluff of the river. These hills are composed entirely of the Buhrstone rocks for a vertical distance of 270 feet. (See Plate XIV, Fig. 3, p. 151.) This is the greatest thickness of Buhrstone rocks that has been measured in one section, except at one other place in the same range of hills.

Above McCarthy's Bluff I failed to find any outcrop of the Hatchetigbee marls, but a short distance northward, on the road to Mount Sterling, some 10 to 11 miles south of Butler, the road descends over 350 feet of Buhrstone rocks, below which I saw in 1885 an indurated greensand marl with fossils embedded in brown sandy clays. This is doubtless one of the Hatchetigbee marls.

The position of the McCarthy's Bluff beds with reference to the Buhrstone and to the Davis's Bluff beds is shown on the general section in Plate XIV, Fig. 3 (p. 151), and in Plate XV, Fig. 3 (p. 155).

Up the Tombigbee River from White Bluff and Davis's Bluff to Wood's Bluff, similar dark gray, sandy clays with darker bands are displayed in the river banks. The thickness of the strata between the Buhrstone and the top of the Wood's Bluff marl is about 175 feet, of which the lower 100 feet are well characterized by a prevailing dark brown or slightly purple color and by the absence of fossils, except an occasional band of lignitic clay or a sandier band with a few marine shells. The upper 75 feet are more fossiliferous and varied in appearance.

In these lower, dark, sandy clays there occur concretionary masses of silicious matter, sometimes almost a flint of approximately spherical shape, and made up of concentric layers or shells. These concentric shells are usually separated by a thin layer of pure quartz of fibrous texture, the fibers being perpendicular to the surfaces of the spheres. These concretions are very commonly looked upon as petrified turtles by the people of the vicinity. They vary from 6 inches to 4 or 5 feet in diameter. In other places the clayey sands themselves are cemented together into rounded concretions, with a nucleus of black lignitic matter.

Where the dark brown or purple, clayey sands above described occur at considerable elevations above the water and have been thoroughly leached and desiccated, they exhibit very much lighter colors. They are

seen under such condition on the hills back of Yellow Bluff, on the Alabama River, and in the country between the two rivers. It is only along the river bluffs and low places, where they are kept more or less moist, that the dark purple and brown shades are so characteristically displayed.

(2) THE WOOD'S BLUFF OR BASHI SERIES. (PLATES XV AND XVI.)

The first beds of marine fossils of any consequence below the series of brown and purple clays above mentioned occur at Wood's Bluff, on the Tombigbee, and just below Johnson's Island, on the Alabama River; also, on Bashi Creek and its tributaries in Clarke County, and at numerous other localities to be given below. We have given to these beds the name of the *Wood's Bluff* or *Bashi Marl.* They are from 15 to 20 feet in thickness, are highly fossiliferous, hold a very considerable percentage of greensand, and the marl has a tendency to become indurated by carbonate of lime into rounded, bowlder-like masses of glauconitic, fossiliferous limestone. These bowlders may be formed in any part of the beds, but are more commonly seen in the upper half, and when this is the case the loose greensand marl below is easily washed out, giving rise to the formation of caves, sometimes of considerable dimensions. Immediately below this marl, and usually within 25 feet of it, are at least four or five thin seams of lignite, varying from a few inches up to 18 inches in thickness.

All these characters render the Wood's Bluff marl easily recognized, and it has been traced by me from the western part of Choctaw across to the eastern part of Monroe County without any essential change in its quality. It has become one of our most important geologic landmarks.

Some 35 to 40 feet below the lowermost of the thin, lignitic beds immediately underlying the Wood's Bluff marl, and separated from it by yellowish, cross bedded sands, is another lignite, about two feet in thickness, at the base of which we wish to draw the line between the Wood's Bluff and the Bell's Landing series. As thus defined, the Wood's Bluff series includes the strata intervening between the purplish brown, sandy clays, above described, immediately overlying the Wood's Bluff marl, and the two feet of lignite. The thickness represented is about 80 feet. The most complete section of the whole series is at Yellow Bluff, on the Alabama River. (See Plate XVI, Fig. 1, p. 159.)

The best exposures of the marl bed are to be seen at Wood's Bluff, on the Tombigbee River, and on the tributaries of Bashi Creek in Clarke County, in the immediate vicinity of Wood's Bluff, although, as stated above, the marl may be readily traced across Choctaw, Clarke, and Monroe Counties, exhibiting at many places away from the rivers very fair sections. On the immediate banks of the Alabama River the marl does not make much show, though it may be seen below Johnson's wood yard.

We give here only three sections, showing the details of the marl bed and of the strata underlying down to the top of the next, or Bell's Landing, series.

(a) *Section at Wood's Bluff, Tombigbee River. (Plate XV, Fig. 1, p. 155, and Plate XVI, Fig. 7, p. 159.)*

Orange sand or stratified drift .... 20 feet or more.
2. Dark brown or bluish black, laminated clays, breaking up into small fragments, 6 to 8 feet, at the upper end of the bluff, but rising to 10 feet or more farther down. These clays are identical with those at the base of the White Bluff section .... 8 to 10 feet or more.
3. Dark bluish, sandy clay, turning red on exposed and weathered surfaces and capped with a hard ledge which may be easily traced down the river nearly to Davis's Bluff[1] .... 3 feet.
3. Bluish, laminated clay or sandy clay, very much like No. 2 in color and texture, but containing no fossils, or very few, and not appearing red at the surface, of variable thickness .... 5 to 8 feet.
4. Bluish or greenish, sandy clay, somewhat indurated, of decidedly reddish color on the surface, highly fossiliferous, characterized by *Turritella lineata* Lea and *Dentalium microstriatum* Heilpr., but containing also *Ancillaria staminea* Con., a small Natica *Pyrula multangulata* Heilpr., *Corbula oniscus*, *Infundibulum trochiformis* Lea, a *Phorus*, and a small oyster. The lower part of this bed passes gradually into the greensand marl No. 5 and is the best collecting ground, as the material is less indurated and the shells are more easily removed .... 3 to 4 feet.
5. Greensand marl to the water's edge .... 10 to 12 feet.

The upper part of this marl is quite soft and friable, but just above the water's edge it becomes indurated and shows a disposition to form rounded, bowlder-like masses, quite hard and firm and resembling a limestone. That this indurated part is of the same nature as the softer greensand above and below it, is seen from the circumstance that the indurated bowlders are sometimes near the top, sometimes near the bottom of the greensand stratum. The accompanying view (Plate VI) shows well the large, bowlder-like masses of the indurated greensand, No. 5. Passing through the central part of this marl bed is a layer of *Ostrea compressirostra* Say, with very thick and ponderous shells.

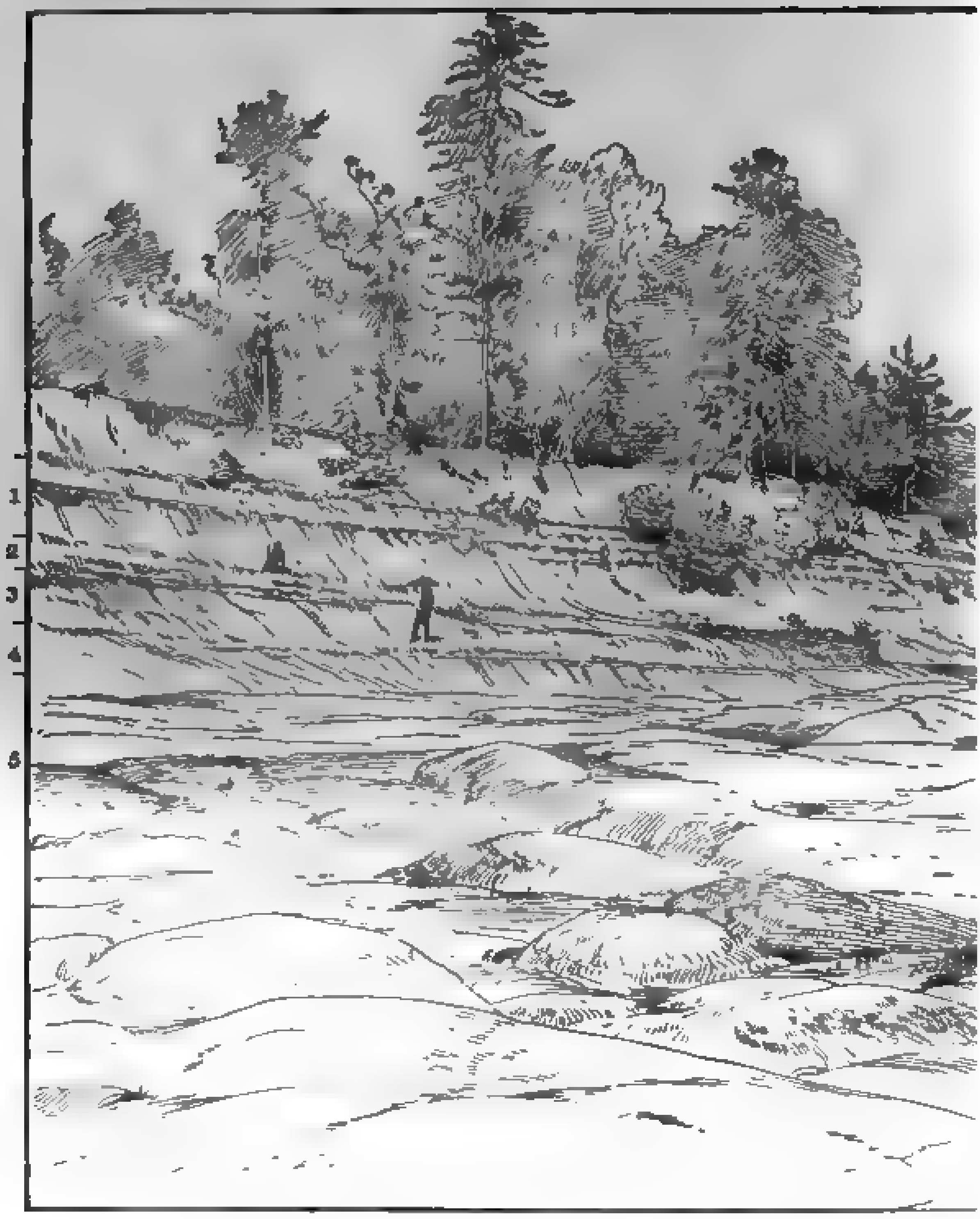
(b) About two miles from Wood's Bluff, on the banks of Basin Creek, there is the following exposure (Plate XVI, Fig. 7, p. 159):

Section near Wood's Bluff.

1. Yellowish gray limestone or indurated marl, like that seen at the base of the Wood's Bluff section .... 10 feet
2. Greenish blue, fossiliferous sands[2] .... 8 feet.
3. Seam of lignitic clay, laminated and jointed .... 6 inches
4. Brown, laminated, joint clay, passing below into a greenish, non fossiliferous sand .... 4 feet.

[1] This bed is highly fossiliferous, containing *Levibuccinum striatum* Heilpr. (which appears to be confined to this particular horizon), *Athleta Tuomeyi* Con., *Fusus pagodiformis* Heilpr., *Venericardia planicosta* Lam., *Actæon pomilius*, Con., a small Natica, *Pleurotoma acuminata* Sow., sharks' teeth, *Ancillaria staminea* Con., a small Cytherea, &c.

[2] These sands are frequently washed out from beneath the limestone or indurated marl, forming caves which are to be seen wherever the Wood's Bluff marl occurs.



1 Dark gray clays ... 2 Bluish sandy clay, fossiliferous ... 3 Bluish sandy clay ...
(The figures refer to sections on p. 44 and

rous. 4. Greenish, sandy clay, highly fossiliferous. 5. Greensand marl.

ection given in Fig. 3 of Plate XVI.)

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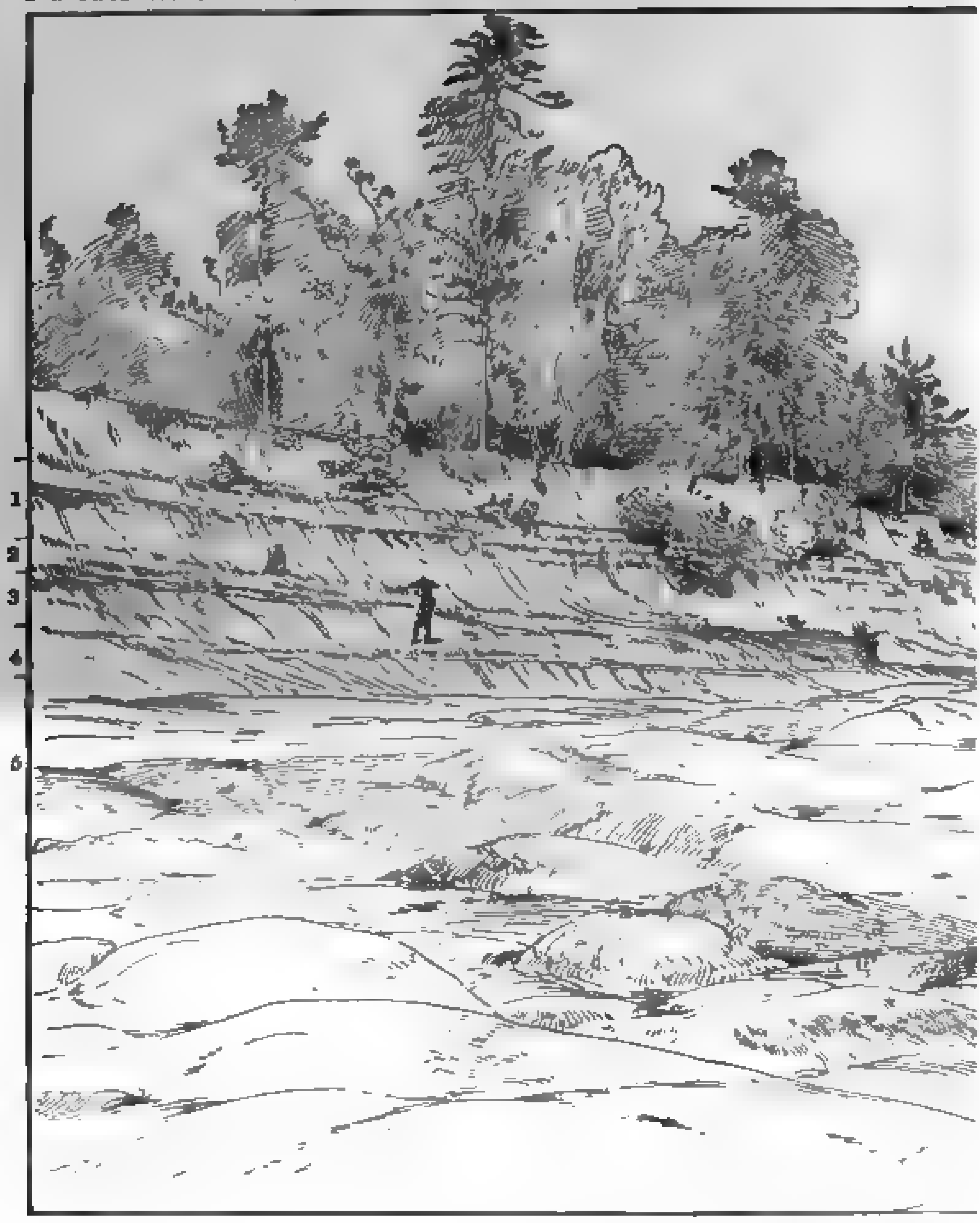

1. Dark gray clays 2. Bluish sandy clay, fossiliferous [illegible]

The figures refer to sections [illegible]

ferous. 4. Greenish, sandy clay, highly fossiliferous. 5. Greensand marl.
section given in Fig. 7 of Plate XVI.)

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landing. The beds numbered 2 to 4, inclusive, together with about forty feet of the lower strata of No. 1, are seen on the top of the bluff, along the road leading up the hill, and they directly overlie the beds exposed in the river bluff. Nos. 2 to 6, inclusive, represent the Wood's Bluff series.

From the sections represented on Plates XV and XVI it will be seen that the Wood's Bluff marl lies embedded in a great thickness of clays and clayey sands, a circumstance which has an important bearing upon its economic value. The disintegration of the clays produces heavy clay soils, which are thoroughly marled by the Wood's Bluff beds, and they form in consequence some of the most productive and lasting soils of the Tertiary group. We have as instances the heavy, calcareous, clay soils which occupy a broad belt north of Butler, in Choctaw County; the productive soils of parts of the Tallahatta and Bashi Creeks region; the clay hill soils of the eastern part of Clarke and the western part of Wilcox Counties, between Choctaw Corner and Lower Peach Tree; the celebrated Flat Creek lands of Monroe County, &c. Some descriptions of these soils, with analyses, were presented in the Report of the Geological Survey of Alabama for 1881-'82.

(3) THE BELL'S LANDING SERIES. (PLATE XVI, FIGS. 1 TO 6, P. 159.)

This series includes two important fossiliferous beds, separated by about twenty-five feet of gray, sandy clays. Between the lignite, which forms the base of the preceding division, and the upper marl of this series there are some forty feet of reddish sands and laminated, gray, sandy clays, and below the lower marl about sixty feet of sandy clays of the prevailing gray color, rather massive in the lower part. About fifty feet below the lower of the two marl beds, and ten feet above the base of this series, there is a third small greensand bed one foot or less in thickness containing fossils. The entire series comprises about one hundred and forty feet of strata, which, as a whole, are gray, sandy clays, becoming more and more massive toward the base, while they are more thinly laminated and more mixed with sands near the summit of the section. The strata which lie between the Wood's Bluff marl and the uppermost of this series are about sixty feet of sandy clays, containing several thin seams of lignite, all of which are exhibited in direct superposition at Yellow Bluff, and have been placed, as above shown, with the Wood's Bluff series. The upper marl bed, which is the Bell's Landing marl bed proper, is some ten feet thick, contains greensand, and indurates into bowlders, fine examples of which are to be seen at the base of the bluff at Bell's Landing. This marl is characterized above all others in the Tertiary of Alabama by containing gigantic specimens of shells which at other localities are of moderate size. The lower bed, known as the Gregg's Landing marl from its occurrence at the landing of that name, is four or five feet in thickness and is of clayey material. It has a peculiar group of fossils.

The fossil bearing beds of this series are best exposed along the banks of the Alabama River at Bell's Landing, Gregg's Landing, Peebles's Landing, Lower Peach Tree, and Yellow Bluff; and on the Tombigbee at Tuscahoma, Turner's Ferry, near the mouth of Shuquabowa Creek, and at Barney's Upper Landing. The exposures on the Alabama are much more satisfactory.

Unlike the Wood's Bluff marl, the marls cf this series make compara tively little show inland from the rivers and exercise little, if any, influence upon either the soils or the topography of the country in which they come to the surface. I am not certain that either the Bell's Landing marl or the Gregg's Landing marl has been identified at any distance from the rivers, while the Wood's Bluff marl can be followed with ease from the Mississippi line as far eastward as we have been.

The following sections illustrate the occurrences of the Bell's Landing beds along the two rivers:

(*a*) *Section at Bell's Landing, Alabama River.* (*Plate XVI, Fig.* 2, *p.* 159.)

1. Yellowish red, cross bedded sands....15 feet.
2. Lignite....about 2 feet.
3. Laminated, sandy clays, with a few large, bowlder-like concretions....10 feet.
4. Yellow, stratified sands alternating with gray, sandy clays....15 feet.
5. Gray, sandy clays....15 feet.
6. Greensand marl forming large concretionary bowlders and holding gigantic specimens of *Rostellaria trinodifera*, *Turbinella pyruloides* Con., *Fusus pagodiformis* Heilpr., *Voluta Newcombiana* Whitfield, &c. The bowlders cover all the lower part of the slope below the landing. The marl beds.... about 6 to 10 feet.
7. Dark gray, laminated, sandy clays, black when wet, but light gray when dry..25 feet.
8. Bluish green, sandy clay marl....1 to 2 feet.
9. Dark gray, sandy clay to water level....4 feet.

Above Bell's Landing the strata of this series are exposed along the river as far as Yellow Bluff, and the most important localities are given below.

(*b*) *Section at Gregg's Landing, Alabama River.* (*Plate XVI, Fig.* 4, *p.* 159.)

1. Greensand marl with concretionary bowlders, the same as No. 6 at Bell's Landing....5 feet.
2. Gray, sandy clays....20 to 25 feet.
3. Dark gray or bluish, sandy clay or clayey sand containing well preserved fossils, many of which are peculiar, and some identical with those at Wood's Bluff, such as *Pyrula multangulata* Heilpr. and *Fusus subscalarinus* Heilpr. This bed has an indurated ledge of variable thickness at the base and is in all...about 4 to 5 feet.
4. Laminated, sandy clays to the water level....about 10 feet.

This bluff extends at least one mile down the river from the landing, and along this whole distance there have been landslides, and the two marl beds have in consequence been thoroughly mixed up. In some places the upper marl has slid down and completely covered the lower; in other places the lower marl is in its proper position, but the upper has slipped down *below* it; sometimes the two are in direct contact, the upper above; but in all cases a careful inspection of the original bluff

(*f*) *Section at Tuscahoma, Tombigbee River.* (*Plate XVI, Fig. 6, p. 159.*)

1. Indurated sands, with a line of bowlders at the base. This stratum is eight to ten feet thick at the warehouse, but down the river it thickens to twenty feet or more, and a second line of ferruginous, indurated bowlders appears about ten feet above the first. The strata above this upper string of bowlders are more distinctly laminated and interbedded with thin sheets of clay. This is most clearly shown about six to eight feet above the upper line of bowlders. Taken all together there are ....about 30 feet.
2. Light bluish gray, sandy clays, which are somewhat striped with harder projecting seams ....35 to 40 feet.
3. Sandy marl, containing the Bell's Landing fossils, but in badly preserved condition ....2 feet.
4. Dark blue, massive clay..3 to 4 feet.
5. Thin streak of greensand, with *Venericardia planicosta* and other Bell's Landing fossils to water level ....6 inches or more.

About half a mile below the landing there is a low bluff capped by the upper string of bowlders above mentioned, which form a little terrace forty or fifty feet wide, the farther limit of which is made by another low bluff of second bottom deposits.

The lignite which occurs about thirty-five to forty feet above the marl bed at Yellow Bluff and at Bell's Landing was not observed at Tuscahoma, those parts of the bluff where it would be looked for being badly weathered.

The massive clay, No. 4, which separates the two parts of the marl bed, is everywhere perforated by pholas, and in most of the perforations their shells are still to be found. Mr. T. H. Aldrich, who made this observation, also saw these shells in the clay which occurs below the lower marl bed at Bell's Landing.

The Tuscahoma (Bell's Landing) marl, with its accompanying beds, may be followed up the river without essential interruption to Barney's Upper Landing, as shown in the following sections (Plate XVI, Fig. 6, p. 159):

(*g*) *Section at Turner's Ferry, Tombigbee River.*

1. Indurated sands, No. 2 of the Tuscahoma section ....5 feet.
2. Marl with badly preserved shells..3 to 4 feet.
3. Bluish clay, becoming sandy below ....3 to 4 feet or more.

From Turner's Ferry these beds rise, going up stream, and at the mouth of Shuquabowa Creek they give the following section:

(*h*) *Section at mouth of Shuquabowa Creek, Tombigbee River.*

1. Greensand marls ....3 to 4 feet
2. Dark bluish black, massive clay ....2 feet.
3. Hard sands, passing into sandy clay below..5 feet.
4. Light colored, nearly white, cross bedded sands, about 3 feet, with 3 to 4 feet below it of sands with clay partings, in all ....6 to 8 feet.

Above this place the strata sink towards the north, and at Barney's Upper Landing only three feet of the beds immediately below the marl are above the water, as seen below.

(*i*) *Section at Barney's Upper Landing, Tombigbee River.*

1. Laminated, sandy clays, striped with somewhat harder and more clayey seams, in all ....15 to 20 feet.
2. Sandy, fossiliferous bed, with greensand in the lower parts, more clayey above. The fossils in this bed are badly preserved, as was the case also at Tuscahoma, Turner's Ferry, &c., but are the characteristic Bell's Landing forms ......5 feet.
3. Dark bluish to gray clays to water level ....3 feet.

From Barney's Upper Landing to the mouth of Horse Creek no Tertiary strata appear on the river banks, but just above that point the river bank is formed by dark gray, clayey sands or sandy clays, which continue up to Williams's Gin, where they overlie the first of the beds containing *Gryphæa thirsæ* Gabb, and in consequence may be better classed with the next section.

(4) THE NANAFALIA SERIES, INCLUDING THE COAL BLUFF LIGNITE

The series of strata to which the Nanafalia marl has given the name, broadly considered, is susceptible of threefold division upon the basis of lithological and paleontological characters, viz :

First. Forty feet or more of indurated, gray clays and sandy clays, in part glauconitic and rather closely resembling some of the materials of the Buhrstone. Near the base of this first division there are hard, sandy clays filled with shell casts, chief among which are Turritellas and Cythereas.

Second. Seventy-five to eighty feet of yellow and reddish and whitish sands, alternating with greensand beds, highly fossiliferous. The characteristic shell in both the sands and the greensands is *Gryphæa thirsæ* Gabb. In the upper fifty or sixty feet of this division this shell is found either in thin greensand beds or sparingly distributed through the other sands. In the lower twenty feet there are thick greensand beds literally packed with these shells. The greater part of the exposure at Nanafalia Landing consists of greensand beds filled with *Gryphæa thirsæ* and other forms, the first named making perhaps 90 per cent. of the whole.

Third. Below the *Gryphæa thirsæ* beds follow some eighty feet or more of sandy clays and sands, variously interstratified, cross bedded sands passing near the base of the division into greensands which overlie a bed of lignite varying from four to seven feet in thickness.

It is easily possible to obtain overlapping sections which embrace the whole series of about two hundred feet; thus in the bluff at Gullette's Landing, on the Alabama River, nearly the whole of the two upper divisions are represented, while on Pursley Creek, a few miles eastward, the lower part of the second division and the whole of the third are shown in direct contact, the whole series being thus represented at two localities.

Between the heavy bedded, sandy clays exposed at the base of the Lower Peach Tree Bluff and those which are seen at the top of the bluff at Gullette's Landing there is a series of glauconitic clays and

clayey sands which have a tendency to harden into pretty firm rocks, having a striking resemblance to some of the materials of the Buhrstone formation, but which are readily distinguished from the latter by one familiar with both of them. These rocks are shown in the hills which rise immediately back of Gullette's Landing and Black's Bluff (Alabama River) to the height of two hundred and fifty to three hundred feet above the river level, and they are seen again in the Grampian Hills of Wilcox County. We have not as yet been able to connect the beds at Lower Peach Tree with those at Gullette's Landing by an overlapping section which includes a part of each, and there is therefore a little uncertainty as to the precise thickness of these beds, though none as to their quality. There is very little doubt that the lower beds of the Lower Peach Tree Bluff are exposed in the hills back of Gullette's Landing and Black's Bluff, but, as already said, this identity is not absolutely made out. The uncertainty, however, cannot concern more than twenty or thirty feet of strata, if so much. Still, it is much to be regretted that even this slight hiatus exists, since from the top of the White Limestone down to this point every foot of the strata has been exhibited in overlapping sections, so that there is not the slightest room for doubt as to their relative position or thickness, nor is there the slightest room for doubt as to relative position here, but only as to exact thickness.

Before giving the section at Gullette's Bluff Landing, some notes concerning the indurated clays and sands that immediately overlie the rocks at the last named locality, and which are seen in the Grampian Hills, will serve to bring out their peculiarities, especially the points of resemblance between them and certain of the materials of the Buhrstone.

About three miles south of Camden, in the Grampian Hills, we find the following:

(*a*) *Section in Grampian Hills, No. 1.*

1. Light-colored, argillaceous, sand rock, containing casts of *Cytherea, Turritella, Voluta*, &c. This passes below into a clayey stratum, which in turn is underlaid by a hard, sandy rock containing many shell casts, particularly of *Turritella Mortoni* Con. .... 5 feet.
2. Gray, clayey beds, breaking into small angular bits .... 5 feet.
3. Ledge of glauconitic, clay rock, sandier below and breaking by joints into large cuboidal blocks of tolerably hard sandstone, containing also a great number of shell casts .... 2 feet.
4. Gray clays resembling those of the Buhrstone, but softer and crumbling more easily .... 15 feet.
5. Glauconitic sands, indurated, filled with casts of *Gryphæa thirsæ* (*first of the Gryphæa thirsæ beds*) .... 2 feet
6. Greensand beds, with perfect shells of *Gryphæa thirsæ* .... 7 to 8 feet.
7. Dark gray clays .... 2 to 3 feet.
8. Yellowish, calcareous sands, with *Gryphæa thirsæ, Flabellum, Venericardia planicosta*, &c .... 4 to 5 feet
9. Bed of *Gryphæa* shells .... 1 foot
10. Yellowish, calcareous sands, with concretionary bowlders, containing *Gryphæa thirsæ* and casts of other shells .... 6 to 8 feet

Half a mile farther south, other beds overlying No. 1 of the above are seen, as shown below.

(*b*) *Section in Grampian Hills, No. 2.*

1. Whitish, sandy rock, indurated, containing shell casts.................... 1 foot.
2. Whitish clay rock.. 1 foot.
3. Hard ledge of sandy rock, with casts of Turritella, Cytherea, &c................ 2 feet.
4. Gray clays, indurated, and greatly resembling some of the Buhrstone clays, 10 to 15 feet.
5. Ledge of indurated glauconitic clay, the lower 12 or 18 inches of which are sandier and filled with shell casts, mostly of *Turritella Mortoni* Con., same as No. 1 of preceding section.. 3 to 4 feet
6. Gray, crumbling clays, with indurated ledge of hard, glauconitic clay in center.. 6 feet.
7. Hard ledge of glauconitic clay or sandstone breaking by joints into large cuboidal blocks... 4 feet or more.
8. Laminated gray clays resembling those of the Buhrstone, breaking up into small bits.. 12 feet,
9. Glauconitic sands, indurated, containing casts of *Gryphæa thirsæ* in the upper part and perfect shells of the same in the lower part.................. 1 foot.
10. Greensand, with occasional shells of *Gryphæa thirsæ*.......................... 5 feet.
11. Yellowish sand filled with shells of *Gryphæa thirsæ*........................ 1 foot.
12. Laminated, yellowish sands, with a few shells of *Gryphæa thirsæ*.............. 4 feet.

The relations between these two sections and the others which exhibit the same strata are more clearly seen in Plate XVII, Fig. 2, p. 163, which is a representation of the two preceding profiles combined.

The Grampian Hills extend westward to the river at the Lookout, which is a cliff reaching fully 275 feet above the river level. This cliff is half a mile or more above Gullette's Landing, and in its lower half the beds which make the bluff at Gullette's Landing are exposed by a landslide in a perpendicular section of nearly 150 feet. Above this a very steep, almost precipitous hill rises 125 feet higher. In this upper part of the hill the rocks are not clearly exposed, but they consist of gray, laminated clays, interstratified with heavy bedded, massive clays, such as are seen in the lower part of the Lower Peach Tree Bluff, with which they are probably, in part at least, identical. No fossils were discovered in these clays, which include in places indurated bowlders of calcareous sand. In the lower part of the hill, hard, glauconitic, sandy clays with shell casts are abundant and correspond in position, as well as in other respects, to those represented in the upper members of the two preceding sections.

At Gullette's Landing a cut has been made for the cotton slide and tramway down to the river level through the strata of the bluff, which are thus very clearly exposed almost as if in a vertical wall.

(*c*) *Section at Gullette's Landing, Alabama River.* (*Plate XVII, Fig.* 1, *p.* 163.)

1. Drift and loam.. 10 feet.
2. Indurated, glauconitic clay, forming ledge.................................. 3 feet.
3. Gray, sandy clays, thinly laminated and heavy bedded alternating.......... 12 feet.
4. Glauconitic sand, very green in places....................................... 2 feet.
5. Gray and sandy clays, like No. 3.. 20 feet.
6. Glauconitic, sandy ledge, fossiliferous (*the first of the Gryphæa thirsæ beds*).. 3 feet.
7. Compact; yellowish sands holding *Gryphæa thirsæ*, and forming a vertical cliff, capped with an indurated ledge a foot in thickness........................ 13 feet.

8. Indurated sandy ledge .... 2 feet.
9. White, cross bedded sands .... 12 feet.
10. Bluish sands, forming a vertical cliff. These contain numbers of *Gryphæa thirsæ* and have an indurated ledge in the midst of the bed, and one at the bottom .... 20 feet.
11. Bluish, clayey sands containing a few *Gryphæa* .... 10 feet.
12. Sands containing *Gryphæa thirsæ*, traversed by several indurated projecting ledges; materials are of darker color and more clayey below to water level .. 20 feet.

At Black's Bluff, Alabama River, about a mile or less below Gullette's Landing, there is a similar section, which, however, is not so clearly exposed. Above the warehouse at this landing, the strata are the same as those at the top of the bluff at Gullette's Landing, but there have been many landslides, by which the relative thickness and positions of the beds here are obscured. Between these two places the river flows approximately along the strike of the strata, which, however, do not lie horizontal, but show one or two undulations with twenty or thirty feet wave height.

The actual contact of the strata of the Bell's Landing and the Nanafalia series fails to appear in the bluffs of the Tombigbee River also, as may be seen in what follows. From Barney's Upper Landing, described in the preceding section, up to the mouth of Horse Creek, no Tertiary beds appear in the river banks. Just above the mouth of this creek grayish, sandy clays occur similar to those which make up the lower 50 feet of the Lower Peach Tree Bluff, and these clays may be traced foot by foot up the river or northward to Williams's Gin, half a mile or so below Gay's Landing, where they are seen overlying the first of the beds holding *Gryphæa thirsæ*. A section of these strata is given below. (See Plate XVII, Fig. 4, p. 163.)

The grayish, sandy clays which overlie these Gryphæa beds are undoubtedly the same as those at Lower Peach Tree, but here also the exact thickness cannot be measured because of their failure to appear in the banks of the river. Still, unless in this short distance of less than a mile there is a fault or a very violent, decided change in the dip of the strata, the thickness of the beds not exposed on the river cannot be much more than fifty feet, if so much.

The strata exposed at Williams's Gin and along the river for half a mile up to Gay's Landing are as follows (see Plate XVII, Fig. 4, p. 163):

(d) Section from Williams's Gin to Gay's Landing, Tombigbee River.

1. Gray, sandy clays, thin bedded, reddish on joint planes, passing below into an indurated ledge of lighter color .... 8 feet.

   About 20 feet more of similar sandy clays appear in the banks of the river, between the mouth of Horse Creek and Williams's Gin, as above mentioned, making the whole thickness actually exposed on this river, between the top of the Gryphæa beds and the bottom of the Bell's Landing marl at Barney's Upper Landing, about thirty feet.[1]

[1] In bed No. 1 above I found a specimen of *Voluta Newcombiana* Whitfield, which heretofore was seen only in the Bell's Landing marl bed and which seemed to be characteristic of it.— E. A. S.

2. Indurated, glauconitic bed, with *Gryphæa thirsæ* .... 2 feet.
3. Dark blue, nearly black, jointed clays, with thin, hard ledges .... 6 feet.
4. Indurated, sandy, fossiliferous bed, with a few *Gryphæa* and other forms. 2 to 3 feet.
5. Bluish black clays, with ferruginous concretions at base .... 3 feet.
6. Greensand bed, with *Gryphæa thirsæ* to water .... 3 feet.

Above Gay's Landing there is a long stretch of several miles in which no Tertiary rocks show on the river banks; but at Lott's Ferry the Gryphæa beds make their appearance again and may be followed thence without material interruption to Eureka Landing and to Nanafalia, a distance in all of perhaps two miles.

These exposures exhibit the following details:

(*e*) *Section at Lott's Ferry, Tombigbee River.* (*Plate XVII, Fig.* 4, *p.* 163.)

1. Dark gray, nearly black, sandy clay, weathering light gray, containing a few fossils .... 5 feet.
2. Indurated, sandy marl, containing *Gryphæa* in places. This bed varies, being in part a cross bedded sand devoid of fossils .... 3 feet.
3. Dark, sandy clays, with a few very badly preserved fossils .... 2 to 3 feet.
4. Glauconitic, sandy beds, with *Gryphæa thirsæ.* This bed is only a few feet thick at Lott's Ferry, but just above shows .... 20 to 30 feet.

All the Tertiary beds about Lott's Ferry exhibit decided undulations. Bed No. 4 of the preceding section sinks entirely below the water and rises again 20 feet or more above it within the distance of a few hundred yards. All these beds probably overlie the section at Nanafalia below given.

At Eureka Landing there are some 20 to 25 feet of a glauconitic, sandy marl (probably the same as part of the upper bed at Nanafalia) filled with *Gryphæa thirsæ*, associated with very few other forms. This makes a tolerably firm rock, which appears in vertical bluffs, usually capped by hard ledges of the same material, and these ledges are mostly strongly phosphatic.[1]

At Nanafalia we have the lowermost of the Gryphæa beds, as shown in the following section:

(*f*) *Section at Nanafalia Landing, Tombigbee River.* (*Plate XVII, Fig.* 4, *p.* 163.)

1. Greensand marl, highly fossiliferous, containing chiefly *Gryphæa thirsæ* Gabb, but holding also *Turritella Mortoni* Con., *Flabellum*, and a few other fossils. This marl makes a tolerably firm rock, with a line of indurated, projecting bowlder-like masses 12 to 18 inches thick of nearly similar material along the whole length of the bluff and near the middle of the bed .... about 20 feet.
2. Dark blue, almost black, laminated clay, devoid of fossils, but passing below gradually into a bluish marl .... 3 to 4 feet.
3. Bluish greensand marl, with a few shells in the upper 3 or 4 feet, but more highly fossiliferous below. This bed contains a great variety of beautifully preserved and easily detached fossils. The fossils can be collected only during very low stages of the water .... 8 to 10 feet.

[1] Specimens of the indurated ledges of the *Gryphæa thirsæ* beds from Nanafalia and Eureka Landing, collected in 1884 by Mr. Langdon, prove to be very decidedly phosphatic; one of the specimens analyzed quantitatively contained 6.7 per cent. of phosphoric acid.

The view (Plate VIII) shows clearly the greensand No. 1, with its line of indurated bowlders along the center. The large rocks in foreground are part of this indurated marl.

The Nanafalia marl, like that of Wood's Bluff, is one of our most important geological landmarks, both because of its tendency to form by induration tolerably firm and weather resisting rocks and because of the influence which it exerts upon the soils. If there were any doubt as to the agricultural value of either the Wood's Bluff or the Nanafalia marls, it would be dispelled by an inspection of the fertile, naturally marled soils produced where these beds come to the surface across the country.

About 60 feet below the lowermost of the beds containing *Gryphæa thirsæ*, above described, there is an important bed of lignite, which shows a thickness of 4 feet at Coal Bluff, on the Alabama River, and of 7 feet at Landrum's Creek, in Marengo County, near Nanafalia Landing. This lignite appears also at many localities in Marengo and Wilcox Counties, e. g., near Shiloh, Magnolia, Hampden, &c., always in connection with the Gryphæa beds, the latter on the summits of the hills, the former 60 feet below in the branches; and, as the Gryphæa marl usually produces very characteristic limy soils, it is not difficult to trace it, as well as the lignite, across the country.

Between the Gryphæa beds and the lignite, the strata are chiefly sands, mostly glauconitic, alternating with sandy clays of grayish colors. The greensands when weathered appear as yellowish or ferruginous sands, and this is the prevailing color upon the hills, while some shade of green or blue characterizes them near the drainage level, where oxidation is less complete. None of these beds are seen on the immediate banks of the Tombigbee River, and only about 30 feet immediately overlying the lignite occur on the banks of the Alabama; but they may all be seen in direct superposition in the hills which border Pursley Creek on the south, where they are laid bare by the road leading from Black's Bluff to Camden.

This section is complete, as may be seen below.

(*g*) *Section on Pursley Creek, Wilcox County.* (*Plate XVII, Fig* 3, *p* 163.)

1. Drift and loam and other beds, much weathered and not further particularized ....10 to 15 feet.
2. Dark colored, crumbling clays ....5 feet
3. Sands containing *Gryphæa thirsæ* and a few other fossils ....5 feet
4. Thin bedded sands and sandy clays, partly glauconitic, with a few obscure fossils ....15 to 20 feet
5. Yellowish gray, cross bedded sands, with concretionary bowlders of the same material. These sands hold also at intervals lenticular sheets of gray clay 25 to 30 feet
6. Interstratified sands and clays, of grayish color with a shade of yellow, rather thin bedded ....10 to 15 feet
7. Gray, sandy clays, exposed in the immediate banks of Pursley Creek below the bridge ....6 to 8 feet.
8. Lignitic clay, thickness not determined

Along the Alabama River no Tertiary strata are to be seen from near Gullette's Bluff to the mouth of Pursley Creek. Just above the last named point, however, there is a continuous exposure of these strata up to Coal Bluff, as shown in the following:

(*h*) *Section between mouth of Pursley Creek and Coal Bluff.* (*Plate XVII, Fig.* 1, *p.* 163.)

1. Greensand at mouth of Pursley Creek ....5 feet.
2. Sands, with an indurated ledge one foot thick at top....................3 feet.
3. Laminated, clayey sands, with a hard projecting ledge at top and one or two lower ones...6 feet.
4. Indurated greensand, forming a ledge ....3 feet.
5. Greensand of softer texture, easily washed out by the waters and forming shallow caves below the preceding ....5 feet.
6. Greensand of firm texture, with a bed of brownish sand one foot thick at the base...8 feet.
7. Lignite of Coal Bluff...4 feet.
8. Firm, sandy clays appearing just above the Coal Bluff Landing............10 feet.

These beds, as exposed on Landrum's Creek (Sec. 23, T. 14, R. 2 E.), are as follows:

(*i*) *Section on Landrum's Creek, Marengo County.* (*Plate XVII, Fig.* 4, *p.* 163.)

1. Bluish green, micaceous sands ....12 to 15 feet.
2. Lignite...7 feet.
3. Dark gray, sandy clay...2 feet.

The lignite here also is 60 feet, by barometric measurement, below the lowermost of the Gryphæa beds, which may be seen on all the hills in the vicinity, where they produce limy soils of great fertility. In most of these limy soils are embedded rounded or water worn fragments of indurated marl.

In many places in Marengo County and elsewhere the greensands overlying the lignite are thoroughly oxidized into a brown iron ore. This may be seen near Magnolia, near Hampden, and near Dumas's Store.

(5) THE NAHEOLA AND MATTHEWS'S LANDING SERIES.

The strata which make up this series are mostly gray sandy clays alternating with cross bedded sands, with a bed at the base of the section containing marine fossils, and consisting of glauconitic sands and dark gray, nearly black, sandy clays. The thickness of these strata varies from west to east, being 150 feet or more on the Tombigbee River, and not more than 125 or 130 at Oak Hill, in Wilcox County.

In 1883 we failed to establish the identity of the Naheola marl on the Tombigbee with that of Matthews's Landing on the Alabama, for the reason that at the former place the upper part of the marl is most conspicuous, and was the only part examined by us, while at Matthews's the bluff is made up of the black or dark gray sandy clays which form the lower part of the marl bed. In the summer of 1886 I made a re-examination of the exposures along the Tombigbee River, and found at

Naheola the black, clayey marl, identical both in material and in fossil contents with that at Matthews's.

On the Tombigbee River there are no Tertiary rocks exposed in the river bluffs between Nanafalia, which lies near the base of the preceding section, and the mouth of Beaver Creek, a distance of about four miles. With an assumed uniform dip of some 30 feet to the mile, this would indicate a thickness of about 120 feet of strata. But from the undulations seen at Lott's Ferry (below Nanafalia) and elsewhere along this river, it is known that the dip is not uniform, and the thickness of the missing beds is probably less than the estimated 120 feet.

From the mouth of Beaver Creek to Naheola there is an almost continuous exposure of Tertiary rocks along the river bank, embracing about 80 feet of strata, making, with the 120 feet estimated above, 200 feet intervening between the base of the Nanafalia marl and the top of the Naheola marl. Of these 200 feet we know from exposures on Landrum's Creek, in Marengo County, and on Pursley Creek, in Wilcox County, the uppermost 60 feet (viz, from the base of the Nanafalia marl down to the Coal Bluff lignite), while at Oak Hill (see below) we have a clear profile embracing at least 130 feet immediately overlying the Naheola marl. This would leave only about 10 feet of unknown beds at the top of our Naheola section, and it is altogether probable that the Pursley Creek and Oak Hill sections embrace the entire series.

The strata which make all the bluffs between the mouth of Beaver Creek and Naheola, as well as the upper part of the bluff at the last named place, consist, in descending order, of about 20 feet of coarse-grained micaceous sands, with projecting, indurated bowlders of sandstone (no fossils observed), with thin clay partings at intervals; below these, about 10 feet of strongly cross bedded sands, seen in the bluffs just below Tompkinsville, and underlying this to Naheola, laminated sandy clays traversed by layers of lighter colored, sandier, and indurated materials; no fossils observed. It is difficult to give a close estimate of the thickness of these last named beds, but it is not less than 50 or 60 feet, and may be 80.

The section (see Plate XVIII, Fig. 3, p. 167) represents the succession and quality of the beds along this stretch of the river.

The lowest of these gray sandy clays are seen at the top of the bluff at Naheola, a few miles above Tompkinsville, where they are underlaid by a marl, and black shaly clays at Naheola, as shown in the following section:

Section at Naheola, Tombigbee River, Sec. 31, T. 15, R. 1 E (Plate XVIII, Fig. 3, p. 167.)

1. Laminated, gray, sandy clays, with two or three indurated ledges eight to ten inches thick, of lighter colored, sandier materials....................18 to 20 feet.
2. Ledge of greensand, oxidized into a brown iron ore of irregular thickness, 3 to 6 inches.

3. Black, shaly, sandy clay ....3 feet.
4. Ledge like No. 2, of irregular thickness ....6 inches.
5. Greensand marl, the upper part indurated, forming a kind of limestone. Both the indurated marl and the limonite, or oxidized greensand above it, hold fossils, prominent among which are an *Arca*, a *Venus*, *Pectunculus Broderipii* Lea, *Turritella Mortoni* Con., *Cardita alticosta* Con., and *Venericardia rotunda* Lea, *Rostellaria trinodifera*, &c. All the fossils are badly preserved. Thickness of bed ....about 3 feet.[1]
6. Black, slaty clay like that occurring on the river above this point to Black Bluff ....10 to 15 feet.

Half a mile or so below Naheola, just below Marengo Shoot, the marl bed No. 5 occurs at the water level, and at Kemp's Landing, a short distance above Naheola, the marl, with its overlying ferruginous concretions, is again seen.

On the Alabama River the Tertiary beds, corresponding to those just described in the vicinity of Tompkinsville, occur between Coal Bluff and Clifton, a distance, by the river, of 10 or 12 miles. On this river there are many interruptions in the continuity of the Tertiary bluffs, so that it would be impossible, from the exposures along the river alone, to get any clear idea of the stratigraphy. All this, however, is made good, as will be seen above, in the sections obtained at Oak Hill and on Pine Barren Creek, in eastern Wilcox County.

The Tertiary beds make the bluffs of the Alabama River at a few localities mentioned below and exhibited in Plate XVIII, Fig. 2, p. 167.

At Burford's Landing, NW. ¼ of Sec. 5, T. 11, R. 7 E., and just above it in Sec. 32, T. 12, R. 7 E., there are low bluffs of laminated and cross bedded sands, alternating with thin seams of gray clay.

At Walnut Bluff, below the mouth of Turkey Creek, the banks are of light colored, yellowish, cross bedded sands, and above Turkey Creek a laminated, sandy clay like so much of the material occurring about Tompkinsville. These clays are devoid of fossils and continue up to Clifton, with very variable dip, the beds being sometimes horizontal, sometimes strongly inclined (nearly one foot in ten), but the average dip is much less, probably somewhere near one in two hundred. It thus becomes very difficult to sum up the thickness of these sandy clays, both because of variable dip and because the bluffs are not continuous.

At Clifton the bluff is 75 feet or more in height, the greater part of the slope being of drift sands, &c., while the Tertiary clays at the base of the hill are only about 10 feet in thickness.

[1] During the summer of 1886 this bed was more closely examined than in 1883, with the result of finding in its lower part a great number of the characteristic Matthews's Landing fossils. Wherever this bed has been exposed to the weather it crumbles down, liberating the shells exactly as at the last-named locality. In 1883 our attention was confined to the upper part of the Naheola bed, with its badly-preserved shells in a greensand matrix; and thus the identity of this bed with that at Matthews's Landing was not so clearly seen.

About one mile above Clifton, on the left bank, of the river, there is a low bluff of black clays, which extends about a mile up the river. These clays have not been closely examined, but they appear quite similar to those better seen higher up, at the mouth of Dickson's Creek, where a bluish black, micaceous, sandy clay, holding many finely preserved fossils, forms the right bank of the river. This is the same bed as that which makes the top of the bluff at Matthews's Landing, a mile or two higher up the river, where we get the following good section of this important deposit:

(*a*) *Section at Matthews's Landing, Alabama River, northern part of Sec. 12, T. 12, R. 6 E.* (*Plate XVIII, Fig. 2, p. 167.*)

1. Bluish or greenish black, micaceous, clayey sand, with finely preserved fossils, very dark when wet, but becoming grayish blue on drying; crumbles upon exposed slopes, liberating the fossils, which lie in the crumbs thus produced. This is capped by an indurated, sandy, concretionary ledge.[1] The thickness of the marl deposit is ....about 5 to 6 feet.
2. Gray sands with a slightly yellowish cast, showing a great tendency to indurate into lens-shaped bowlders, 1 to 2 feet thick and 3 to 4 feet wide. The sands are also fossiliferous, but much less so than the preceding; the fossils are difficult to get out because of the hardness of the material.............3 to 4 feet.
3. Bluish, micaceous, clayey sand, much like No. 1, but not holding all of its characteristic fossils. Where this stratum lies exposed to the sun and weather upon flat or nearly horizontal benches, it disintegrates, like No. 1, into crumbs, in which the liberated fossils lie loosely, but where it forms vertical bluffs, it is firm and compact and resembles black clay ....7 to 8 feet.

This lowermost bed is sandy above and clayey below, and the material of the whole bluff might be better described as a bluish black, sandy clay, divided into two parts by a bed of calcareous sand, which reaches up into the upper clay bed and down into the lower by gradual transition. The beds which compose this bluff are seen along the river for a mile or more, and are approximately horizontal in position, since the river in this part of its course runs in the direction of the strike of the beds.

The Matthews's Landing marl bed is seen eastward of the Alabama River at very many places in Wilcox County, and it holds usually a number of well-preserved fossils. Near Mr. Clarence Jones's, 7 miles east of Camden, on the Allenton road, there are a good many exposures of this marl bed in the gullies, and we get a very fair section of some 30 feet of the underlying rock. At Oak Hill and in Dale's Branch (see below) we have other good outcrops of the marl. The consideration of this fine section, which includes also the underlying beds down to the base of the Tertiary, we shall leave till after the description of the occurrences along the two rivers.

[1] This is probably one of the glauconitic, concretion-forming sands which are so characteristic of the marl of Naheola.

(6) THE BLACK BLUFF SERIES.

This section has been named from its most characteristic exposure at Black Bluff, on the Tombigbee River, in Sec. 12, T. 16, R. 1 W., in Sumter County, which is as follows:

(*a*) *Section at Black Bluff, Tombigbee River.* (*Plate XVIII, Fig.* 3, *p.* 167.)

1. Yellowish clay, which makes the basis of the Flatwoods, occupying top of bluff .... about 20 to 25 feet.
2. Black, slaty clay, fossiliferous .... 40 feet.
3. Brownish shale or clay to water level .... 8 to 10 feet.

The black clay, No. 2, contains marine fossils, the most prominent among which are a little coral, an Arca, fragments of the shells of a large Nautilus, parts of crabs, &c.

The lower part of the bluff at this place is covered with singularly shaped concretionary masses of limonite. The surfaces of these concretions are marked off into rhomboidal plates, like the markings on an alligator skin. The shales or black clays are strongly calcareous, which accounts for the limy character of some of the soils derived from them in Marengo and Wilcox Counties.

In Sumter County a bed of lignite is found near the summit of the black clays, and just beneath the yellowish clays of the above section.

All the bluffs from Black Bluff down to Naheola, above described, are composed of a black clay in most respects similar to No. 2 of the above section.

The fossiliferous bed of Black Bluff may be seen at any of the exposures as far down the river as Griffin's Landing, 7 or 8 miles, nearly along the strike of the strata. Below Griffin's, down to Naheola, the black clay of the bluffs is quite hard and compact, breaking with conchoidal fracture and resembling very closely the black shale of the Devonian formation. No trace of a fossil could be detected in the black clay along this long stretch of the river. At Lewis's Lower Landing, Beckley's, Oakchia, Steiner's, Kemp's, and Naheola the clays are usually covered with the singular limonite concretions remarked upon at Black Bluff.

The distance across the strike of the rocks, from Black Bluff to Naheola, is about 7 or 8 miles, and through this distance the only Tertiary rocks which appear on the river banks are black clays. Upon the assumption that the dip of these rocks is uniformly about 30 feet to the mile, this would indicate a thickness of nearly 200 feet. But we have seen above that undulations are not rare in the Tertiary rocks, so that the actual thickness is probably very considerably less than 200 feet. The Bladen Springs boring (Plate XXI, column 4, p. 183), shows, according to our interpretation of it, only about 100 feet of black clays above the Rotten Limestone, and a part of this may belong to the Ripley group of the Cretaceous.

As to the equivalence of this black clay group, there is no doubt that it in part represents the Flatwoods group of Dr. Hilgard, because these Flatwoods, so well developed in Mississippi, extend down into Sumter County, in Alabama, and across it to the Tombigbee, and thence across Marengo to the Alabama, which they touch at Midway, a short distance below Prairie Bluff. So far as I am aware, they have not been identified in Wilcox County, although the fossiliferous stratum of the Black Bluff group is very characteristically developed across this county, as may be seen from the sections still to be given.

These Black Bluff clays in Sumter and Marengo Counties contain very little lime, and form Post-Oak Flatwoods with stiff clay soil, while east of the Alabama River they become more and more calcareous, and form the basis of the prairies in Wilcox County and eastward. Even in Marengo County the lower part of the Black Bluff clays is much more calcareous than the upper, and we find a narrow belt of black prairie land lying just north of the Post-Oak Flatwoods. This prairie soil merges by almost imperceptible gradations into the genuine Flatwoods.

7. THE MIDWAY SERIES.

Between Matthews's Landing, above described, and Midway there are no Tertiary rocks exposed along the banks of the Alabama River.

The bluff at Midway is half a mile or more in length, the dip of the strata quite variable, but very considerable, in places as much as one in thirty, and in some places the beds are nearly horizontal. At the lower end of the bluff appear black clays similar to those at Matthews's Landing or Black Bluff, a few feet only showing, and these apparently without fossils. These clays overlie about 10 feet of light colored argillaceous limestone, with projecting hard ledges. This limestone contains the large Nautilus (Enclimatoceras) which characterizes the lowermost Tertiary beds about Pine Barren Creek below mentioned, and it is no doubt identical with the Nautilus rock of eastern Wilcox.

This Nautilus rock has been recognized in that part of Wilcox County lying west of the Alabama River, and it has been traced thence across Marengo County to Moscow, on the Tombigbee River. Southward of the localities where it forms the surface appears always a strip of black prairie soils, derived from the disintegration of the calcareous clays (of Black Bluff group), which immediately overlie the Nautilus limestone, and southward still of this prairie belt lies the belt of Post-Oak Flatwoods, the soils of which come from the disintegration of the non-calcareous clays of the Black Bluff group. The Flatwoods belt, as has already been intimated, does not appear to extend beyond the Alabama River towards the east, while the prairie belt attains to greater and greater importance in that direction.

Midway is some 4 miles down the river from Prairie Bluff, where occurs the first outcrop of Cretaceous rocks on the Alabama.

Between these two points there are none but comparatively recent deposits along the river banks.

The position and character of the Tertiary rocks exposed at Midway may be seen on Plate XVIII, Fig. 2, p. 167.

THE OAK HILL AND PINE BARREN PROFILE.

This profile embraces the strata of the Naheola or Matthews's Landing, the Black Bluff, and the Midway sections above described, and gives us a continuous view of all the strata from just below the Coal Bluff lignite down to and including the uppermost beds of the Cretaceous. Our three lowest sections of the Lignitic might with propriety be classed together as the Oak Hill Pine Barren group.

About half a mile to three-quarters west of Oak Hill, in Sec. 16, T. 11, R. 10 E., in Wilcox County, the Allenton and Camden road descends a long hill, where at least 150 feet of the Tertiary strata are laid bare.

(a) *Section near Oak Hill, Wilcox County.* (*Plate XVIII, p.* 167.)

Red loam, pebbles, &c. of the Drift.

1. Cross bedded sands and thinly laminated clays, much decayed and difficult at times to distinguish from the overlying red loam .... 25 feet.
2. Gray, cross bedded sands, alternating with thin laminæ of gray clay; general aspect of the whole, gray .... 40 feet.
3. Bed of yellowish gray, cross bedded, and laminated sand .... 18 inches.
4. Thinly bedded, gray clays, interstratified with thin ledges of cross bedded sands .... 30 feet.
5. Sands 1 foot, clays 1 foot, sands 1 foot .... 3 feet.
6. Gray clays, interstratified with cross bedded sands .... 6 feet.
7. Gray, cross bedded sands with very little clay .... 3 feet.
8. Gray clay breaking up into cuboidal blocks, interstratified with sandy ledges .... 15 feet.
9. Black to gray micaceous sands, with the fossils of Matthews's Landing ..... 7 feet.
   This bed is darker at top and lighter colored at bottom. In Dale's Branch, close by, the same bed occurs with glauconite in part of it. It is quite possible that part of this bed may be identical with the Naheola marl. At other localities, near Oak Hill, this bed has a greater thickness, and the above may be taken as the lower limit. According to the observations of Mr. Johnson, in a well bored at W. W. McConnico's, the thickness goes even to 20 feet, thus approximating the thickness at Matthews's Landing.
10. Hard ledge of calcareous glauconitic sand .... 1 foot.
11. Yellowish, calcareous sands, with white lime concretions and one or two harder ledges .... 12 feet.
12. Glauconitic sands with indurated ledge at top .... 10 feet.
13. Sandy shales, with indurated ledge .... 5 feet.
14. Hard, yellowish, sandy limestone, with phosphatic nodules, appearing also in the Graveyard Hill section, No. 3 .... 2 to 3 feet.

This bed is a very conspicuous feature in all this vicinity; it may be seen on the sides and summits of most of the low hills, where, breaking off in consequence of joint planes, it appears like a low stone wall running around the hills. From the locality above given to the Graveyard Hill this stratum can be followed with certainty, and appears as above stated in the accompanying section.

(b) Section on Graveyard Hill. (Sec. 5, T. 11, R. 10 E.)

1. Grayish white, calcareous sands, with small phosphatic nodules, characterized by an abundance of crustacean remains ....5 feet.
2. Whitish, calcareous sands, with several harder ledges which shale off in weathering ....20 feet.
3. Hard, yellowish, sandy limestone, containing small phosphatic nodules. This is the rock which forms the walls around all the low hills in the vicinity .2 to 3 feet.
4. Yellowish, calcareous, clayey sand, with white lime concretions, becoming grayer in color and more clayey, and containing numerous fossils identical with those found at Black Bluff ....15 feet.
5. Black, calcareous clays, yellowish gray on weathered surfaces, also containing the Black Bluff fossils, but less abundantly than the preceding bed .20 feet or more.

This black clay and the overlying bed yield the prairie soils of this section of Wilcox County. These soils are exceedingly fertile, as may be seen by the fine crops which grow upon them and by the immense height of the weeds which spring up by the roadsides.

Graveyard Hill, like all the others in the vicinity, slopes off into the prairie fields which border Prairie and Pine Barren Creeks. In the lower parts of these fields we come always upon a ledge of rocks, decribed below, which forms the continuation of the section above given. Below this rocky ledge occur sands and sandy shales, which undoubtedly belong to the Cretaceous formation.

The whole thickness of the clays, &c., which form the prairies here is about 30 to 35 feet, so that what follows is only the direct continuation of the preceding section.

(c) Section from base of Graveyard Hill to Pine Barren Creek.

Black clays, weathering yellow, basis of prairies, No 5 of the preceding section

6. Hard, grayish white limestone, characterized by great numbers of a large *Nautilus* (*Enclimatoceras Ulrichi*), and hence known as the Nautilus Rock .. about 10 feet.
7. Calcareous sands forming basis of the black, sandy prairies of this vicinity ..6 feet
8. Hard, yellowish white, crystalline lime rock, sandy in places and filled with red specks, highly fossiliferous, containing *Turritella* in great numbers, also *Carditas*, a *Rostellaria*, *Ostrea*, and two or three species of coral. This is one of the most persistent of the lower Tertiary rocks towards the east ....8 feet
9. Yellowish, micaceous sands, with Cretaceous fossils ....55 feet
10. Bluish gray, calcareous sands, with two very prominent ledges 4 feet apart, and two or three smaller ledges Thickness to water level below Palmer's Mill ....15 feet.

These three sections are illustrated in Fig. 1 of Plate XVIII, p. 167.

It may be remembered that from the summit of the White Limestone down to the base of the Bell's Landing section of Lignitic, representing about 1,200 feet, our geological column is uninterrupted and is covered throughout by overlapping sections.

Below the Bell's Landing section occurs the first hiatus or break in this column, the first place where we have as yet been unable to connect two contiguous divisions by overlapping sections.

Immediately below the Coal Bluff lignite of the preceding section there is a second gap, the exact dimensions of which we have as yet not been able to ascertain. Making the highest estimate (based upon an assumed uniform dip of the strata of 30 feet to the mile), the thickness of the beds here concerned can hardly be more than 50 or 60 feet, for the missing beds should outcrop along the Tombigbee River between Nanafalia Landing and the mouth of Beaver Creek, a distance of 4 miles, corresponding to a thickness of 120 feet. We know, from exposures on Landrum's Creek and Pursley Creek, all the beds below the Nanafalia marl down to the lignite, 60 feet below, so that the missing beds would constitute the other half of this estimated 120 feet.

On the Alabama River, likewise, we see some ten feet of strata below the lignite, after which follows a barren stretch of river bank which shows no Tertiary beds at all for two or three miles.

In the Pine Barren profile, which gives so complete a view of the lower part of the Tertiary formation, the lignite is not seen in actual contact with the beds of this section, so that here, also, we have the gap unfilled. From the occurrence of the lignite, however, a short distance south of Oak Hill, which makes the summit of the Pine Barren section, the thickness of the beds involved in this gap is here also shown to be not very great, except upon the assumption of a very abrupt change in the dip of the strata, which is wholly unauthorized by any facts which have come under our observation.

Geologically below this gap, from the mouth of Beaver Creek, on the Tombigbee, to Black Bluff (up the river), there is an almost continuous exposure of Tertiary beds along the river banks, but there is difficulty in getting the exact thickness of the beds thus exposed.

On the Alabama River the exposures are much less continuous, and the thickness of the beds correspondingly more difficult to ascertain.

It is therefore fortunate that we have, in the Pine Barren region, a continuous section of 240 to 250 feet, embracing all the beds below the gap or hiatus named, down to the top of the Cretaceous formation.

This section is exposed at two localities, above given, viz: Along the Camden road, about half a mile west of Oak Hill, and at the Graveyard Hill in Sec. 8, T. 11, R. 10 E., the lower beds of Oak Hill appearing in the upper part of the Graveyard Hill. The lower portion of the section appears at the base of the latter hill and along the low grounds of Prairie Creek down to Palmer's mill on Pine Barren Creek. All the lower part of this section, up to the Dale Branch or Matthews's Landing marl, was very carefully worked out in 1883 by Mr. Johnson, and the section continued by estimates up to the Nanafalia beds, which appear at Eggville, in Sec. 22, T. 11, R. 10 E. To Mr. Johnson also belongs the whole credit of determining beyond doubt the exact limit between the Tertiary and Cretaceous rocks in eastern Wilcox.

He has shown that the Nautilus (Enclimatoceras) Rock, which had, up to 1883, been considered Cretaceous, overlies a crystalline limestone

holding *Turritellas*, *Carditas*, a *Rostellaria*, and other Tertiary species. The measured section from Chambers Creek across Pine Barren Creek up to the summit of the Graveyard Hill profile (see Plate XVIII, Fig. 1, p. 167) was also made by him.

In the summer of 1885 these localities were visited by the present writer, when the measured part of Mr. Johnson's section up to the Dale Branch or Matthews's Landing marl was fully verified and extended by the addition of some 125 feet of strata exposed along the Camden road, near Oak Hill, and in direct superposition over the Dale Branch marl. Notwithstanding the 125 feet thus transferred from "estimated" to the firm ground of "measured" strata, there still remains, as above stated, a gap not covered by overlapping sections between the top of the Oak Hill section and the Coal Bluff lignite.

It would be manifestly a serious omission on our part not to speak in this connection of the observations of Prof. Alexander Winchell, made in 1856 in eastern Wilcox County.[1]

This author recognized as Tertiary, and described in sufficient detail to render their identification easy, several of the beds included in our Pine Barren sections below given, notably No. 3 of the Graveyard Hill and the underlying marls containing Black Bluff fossils, and also the Turritella rock which lies at the base of our Tertiary section, and he rightly extends the line between the Tertiary and Cretaceous to a point eight and a half miles north of Allenton.

These rocks he, however, places in the Buhrstone, and above his Buff Sand, which he considers the lowermost of the Tertiary rocks. By comparing our Nanafalia sections and Professor Winchell's description, it will be seen that his Buff Sand overlies (at Black's Bluff on the Alabama River) the beds with *Gryphæa thirsæ*, which at that time was generally considered a Cretaceous species. These beds we now know are some 300 feet above the top of the Cretaceous.

Notwithstanding some mistakes in fixing the relative positions of rocks observed at widely distant localities, mistakes which were probably unavoidable without long-continued observations, we find recorded in this pioneer work of Professor Winchell a host of sagacious observations which have been fully confirmed by those who have since gone over the same ground.

In this part of the Tertiary the variations in the thickness of the beds and the quality of the material as we go from west to east are more striking than in the overlying strata. Thus, on the Tombigbee River, near the base of the Tertiary, there is a great thickness of black, sandy clays (80 feet or more in one place, Black Bluff), which extend down the river for many miles, to Naheola, while on the Alabama the only rocks seen of this kind are at and near Matthews's Landing, which is near the top of the series; and in the Pine Barren section in eastern

[1] Proceedings Am. Assoc. Adv. Sci., Part II, pp. 87–89, 1856.

Wilcox County, where all the strata are shown, the whole thickness, including the Matthews's Landing marl, is not greater than 75 feet.

On account of these differences it becomes impossible, without further comparison, to correlate some of the beds of the Tombigbee section with those exposed at Oak Hill and on Pine Barren Creek.

In the vicinity of Palmer's Mill (Smith's bridge), on Pine Barren Creek, in Wilcox County, we have the lowermost of the Tertiary beds in direct contact with the uppermost of the Cretaceous. At this place the beds of the two formations appear to be strictly conformable with each other. Here, also, the lower Tertiary beds have a very striking resemblance in lithological characters to some of the Cretaceous beds; but the fossils, as Mr. Johnson has shown, leave no room for doubt as to the age of the beds.

This resemblance is most pronounced in the case of the shaly sandy beds of Graveyard Hill, which might easily be mistaken for similar beds occurring at Canton Landing and back of Prairie Bluff. The latter are of Ripley age, while the Graveyard Hill rock overlies sandy clays holding Black Bluff fossils. So, also, the Nautilus rock might well pass for Cretaceous, except that it overlies a limestone holding Turritellas, Carditas, and other fossils which Mr. Johnson has identified as Tertiary. No one can fail to be impressed with the similarity in general aspect, if not in the organic contents, of the contiguous beds of the two formations.

THE BLADEN SPRINGS BORING.

In the years 1884 and 1885 a boring was made at Bladen Springs, in Choctaw County, in search of petroleum. The carefully kept record was obtained from Captain Trowbridge, who had charge of the boring.

The surface rocks at the place of boring are either the lowermost of the Buhrstone or, more probably, the uppermost of the Hatchetigbee, the loose surface materials hiding the Tertiary rocks at the locality. The boring penetrated through the underlying Tertiary rocks, through the Ripley, and 125 feet (as we interpret it) into the Rotten Limestone of the Cretaceous. We have inserted this record, drawn to scale, in its proper place in the general section (see Plate XXI, column 4, p. 183), where it will be seen the thickness revealed by the boring corresponds very well with that established by our measurements. It is, however, difficult to correlate with any certainty the beds penetrated by the boring with the strata of the general section, since an accurate determination of the lithological and other characters of the beds from the loose and mingled materials brought up by the auger is manifestly impossible; still, we have felt warranted in several instances in pointing out the probable equivalences. In the lower part of the boring, especially, we think that the black or dark blue clays and clayey sands of the Black Bluff and Ripley sections are unmistakably shown, as is also the Rotten Limestone, although in the boring there appear only 17 feet of sands at

base of the Ripley, while in some places, as at Prairie Bluff, the thickness is at least 60 feet.

In 1884, while the boring was still in progress, Mr. D. W. Langdon, jr., visited Bladen Springs, and, upon the authority of our much less perfect river section, predicted that the Rotten Limestone would be reached at 1,200 feet. In reality it was reached at 1,220 feet.

§5. SUMMARY OF THE LEADING FEATURES OF THE TERTIARY STRATA OF ALABAMA (PLATE XXI).

With a brief review of the distinguishing characteristics of the divisions of the Tertiary above made, we conclude this part of our subject.

The whole thickness of the strata of the Tertiary group of Alabama occurring in the vicinity of the two rivers is between 1,620 and 1,700 feet. This estimate is based upon actual measurement, except at one or two horizons, and even in these places we are able to give a close estimate of the thickness of the strata not measured.

We have adopted the following fourfold division of the Tertiary:

(1) The White Limestone,
(2) The Claiborne,
(3) The Buhrstone, and
(4) The Lignitic.

In all that follows, the strata are described in descending order.

(1) THE WHITE LIMESTONE.

This subdivision is calcareous throughout, but the lowermost 60 feet are more argillaceous than the rest. The minimum thickness is 350 feet, of which the uppermost 150 feet consist of a tolerably pure but somewhat silicious limestone, filled with coral masses. The next succeeding 140 feet or more are made up of a soft, white limestone, often quite pure and filled with *Orbitoides Mantelli*. The lowermost 50 feet are of impure, argillaceous limestone, which in disintegrating yields a black, calcareous soil similar to that derived from the Rotten Limestone of the Cretaceous. This lower portion of the White Limestone surpasses the others in the variety of its fossil contents.

(2) THE CLAIBORNE.

The thickness is 140 to 145 feet, the materials are sands and clays, which are generally calcareous and often glauconitic. Near the top of the subdivision is a bed of glauconitic sand 15 to 17 feet in thickness, filled with shells in a perfect state of preservation. The sandy clays forming the lower 30 feet are likewise filled with a great variety of shells in a good state of preservation. The intervening calcareous clays and calcareous sands are distinguished by the great numbers of shells of *Ostrea sellæformis* which they hold, as well as by the comparative rarity of other forms.

(3) THE BUHRSTONE.

The minimum thickness of this formation is 300 feet; the materials are almost altogether aluminous and silicious, consisting of aluminous sandstones, claystones, and quartzitic sandstones, with occasional thin beds of glauconitic sand. The few fossils which have been obtained from this division are mostly in the form of casts. They do not appear to differ specifically from those of the overlying division.

(4) THE LIGNITIC.

This is the most massive of the subdivisions of the Tertiary, having a thickness which can hardly be less than 900 feet. It also presents a greater variety in mineral composition, as well as in fossils, than the other divisions. In the most general terms, the Lignitic strata are cross bedded sands, thin bedded or laminated sands, laminated clays and clayey sands, and beds of lignite, as well as the lignitic matter which merely colors the sands and clays. With these are found interbedded, at several horizons, strata containing marine fossils. For the sake of greater convenience and clearness of description we present the Lignitic in seven sections, each of which is characterized by one or more beds of marine fossils included in it. These sections are as follows:

(*a*) *The Hatchetigbee section.*—This section is 175 feet in thickness, made up of sandy clays of prevailing brown or purplish color, containing three or four beds of marine fossils in the uppermost 75 feet, and of somewhat similar purplish brown, sandy clays nearly devoid of marine fossils in the lower 100 feet. All these brown, sandy clays become much lighter colored upon drying and exposure to the weather.

(*b*) *The Wood's Bluff or Bashi section.*—This is 80 to 85 feet in thickness. The uppermost 30 feet of the section consist of dark brown clays passing into a greensand, which holds a great variety of finely preserved marine shells. Below this greensand marl are gray, sandy clays, with four or five thin beds of lignite within the first 25 feet, succeeded by about 30 feet of cross bedded sands, with a two foot seam of lignite at the base.

(*c*) *The Bell's Landing section.*—This is 140 feet in thickness, and includes two important marine beds, and a third, quite small and apparently unimportant. These fossiliferous beds are interstratified with yellowish sands in the upper and rather heavy bedded, sandy clays in the lower part of the section. The upper marine bed, called the Bell's Landing marl, is about ten feet in thickness and has 40 feet of sandy strata above it. The middle bed is called the Gregg's Landing marl, and it is twenty to twenty-five feet below the preceding; it is about five feet in thickness. The lowermost of the fossiliferous beds of this section is only about one foot in thickness and lies about fifty

feet below the Gregg's Landing bed. It is highly glauconitic, but does not contain any great variety of fossils. The Bell's Landing marl is distinguished from all others in Alabama by the great size of the shells which it contains.

(*d*) *The Nanafalia and Coal Bluff section.*—The strata of this section are 200 feet in thickness and consist of about fifty feet of gray sandy clays at top, which show a tendency to indurate into tolerably firm rocks resembling very closely some of the strata of the Buhrstone. Below this, about eighty feet of sandy beds, often strongly glauconitic, characterized throughout by shells of a small oyster, *Gryphæa thirsæ*. Near the base of this sandy division there is a bed about twenty feet thick, literally packed with these shells. Below the *Gryphæa thirsæ* beds follow some seventy feet of cross bedded sands, glauconitic and apparently devoid of fossils, including, about ten feet from the base of the section, a bed of lignite which varies in thickness from four to seven feet.

(*e*) *The Naheola and Matthews's Landing section.*—It is difficult to give the precise thickness of this section, since it varies on the two rivers. We have placed it at one hundred and thirty to one hundred and fifty feet; the strata are gray, sandy clays in the main, alternating with cross bedded sand. The beds of dark, sandy, and glauconitic clay, containing marine fossils, lie at the base of the section. At Naheola on the Tombigbee the upper and more glauconitic part of the bed is most prominent, while at Matthews's Landing on the Alabama, the lower part of the bed, dark gray sandy clay forms the bluff.

(*f*) *The Black Bluff section.*—Here again we have difficulty in determining the exact thickness, since on the Tombigbee the strata of this section are spread over an extent of surface which would, with uniform dip, correspond to a thickness of over two hundred feet, while on the Alabama, and more particularly inland in the eastern part of Wilcox County, the thickness is not greater than thirty-five or forty feet. Since 80 feet of these beds are seen in superposition at one locality (Black Bluff), we think that the maximum thickness cannot be less than one hundred feet. The characteristic strata which compose nearly the whole of this section are black or very dark brown clays, which are in part fossiliferous.

(*g*) *The Midway or Pine Barren section.*—Thickness, 25 feet. The strata are: a white, argillaceous limestone holding a large nautilus, which is characteristic of the horizon, 10 feet; calcareous sands and a yellowish, crystalline limestone, with Turritellas, Carditas, and corals, the sands 6 feet, the limestone 8 or 9 feet. This section is best seen in eastern Wilcox County on Pine Barren Creek, but the upper or Nautilus rock occurs at Midway, on the Alabama River, and westward across Marengo County. No exposure was noticed on the Tombigbee, but it will probably be found a short distance below Moscow.

II. CRETACEOUS STRATA.

The Cretaceous formation in Alabama exhibits three well marked divisions, which, in descending order, are as follows:

First. A series of yellow sands, dark gray or bluish, sandy, micaceous clays, impure limestone, and sands again, in all between two and three hundred feet in thickness. This has been called the Ripley formation by Hilgard, and the name is retained for Alabama.

Second. An impure, argillaceous limestone of tolerably uniform composition and about one thousand feet in thickness, known as the Rotten Limestone.

Third. A series of laminated sands and sandy clays at least three hundred feet in thickness which has been named the Eutaw formation.

All these strata, especially the calcareous parts, are more or less perfectly exhibited in the bluffs of the two rivers.

It will be seen below that we have not as yet been able to construct the column of strata of this formation with as great a degree of completeness as has been done for the Tertiary, but this want of completeness is in the figures showing the thicknesses of the several strata rather than in the succession and quality of these beds.

§1. THE RIPLEY FORMATION.

The character of the uppermost beds of this formation immediately underlying the Tertiary was first clearly determined by Mr. Johnson in the Pine Barren section, in the eastern part of Wilcox County, already given above. These uppermost beds were afterwards traced by him westward to the Alabama River and eastward to Clayton and Eufaula. The relation of the Bridgeport horizon to the yellow sands was also first determined by him. In 1885 the strata connecting the Bridgeport section with the Prairie Bluff section were determined by Mr. Langdon and myself, and it is believed that we now have the complete section of the Ripley strata along the rivers, except that the actual contact with the Rotten Limestone of the sands forming the lower part of Prairie Bluff, has not come under observation. The uppermost beds of this formation were also examined in 1885 by Mr. Langdon and myself in Marengo County, south of Dayton, as described below.

The strata of the Ripley formation, according to the investigations above alluded to, are as follows:

First. Fifty-five feet of yellow sands, not recognized on the Tombigbee River, but constituting the upper part of the bluff at Bridgeport, on the Alabama River, and much better developed in the hills immediately back of the bluff. From here they may be traced across the country for a great distance eastward. Mr. Johnson has probably identified this sand at Clayton, in Barbour County, where it constitutes

the basis of the fields on the south side of Barbour Creek. In this sand on the road between Eufaula and Clayton were found decayed shells of a small oyster, and with them *Exogyra costata* Say in a pretty good state of preservation. The same oyster, without the Exogyra, was seen in the eastern part of Wilcox County, on Prairie Creek.

Second. About one hundred feet of bluish, micaceous, sandy clays, somewhat calcareous, marked at intervals of ten or fifteen feet throughout the whole thickness by the occurrence of indurated ledges, usually of rather sandier texture. These ledges appear occasionally as shaly sandstones of very little hardness, flaking off readily into sheets under the influence of the weather. Our observations in the Canton Bend and in the hills between Prairie Bluff and Rehoboth, and also westward towards Linden, in Marengo County, and eastward in Dallas and Wilcox Counties, have shown that these sandy clays, where they lie high above the drainage and well exposed to the action of the weather, lose altogether their bluish color and appear in all shades of yellowish gray. This difference in color, depending upon the degree of oxidation of certain constituents of the strata, especially the iron bearing materials, has not unfrequently been observed in the strata both of the Tertiary and of the Cretaceous groups. The most striking instance of this sort is to be seen at Prairie Bluff, where the sands forming the lower part of the bluff exhibit a dark blue, almost black color near the water's edge, while the same stratum is seen to be a white sand where it outcrops at the top of the bluff higher up the river.

Later observations in 1886 by Mr. Langdon and myself have shown clearly that the differences in these yellow sands and bluish micaceous sandy clays arise merely from different degrees of oxidation. In some of the outcrops observed by us, e. g., in Little Texas, Butler County, and in Lowndes County, bluish, micaceous sands, identical in appearance with those making the lower part of the Bridgeport Bluff, are seen along the banks of Cedar Creek directly underlying the Nautilus rock and Turritella limestone which lie at the base of the Tertiary. The same thing may likewise be seen in the upper part of Marengo County, where it has been found impossible to separate the yellow sands from the bluish, sandy clays.

Third. Calcareous beds some twenty feet in thickness, holding great numbers of Cretaceous fossils, some well preserved, others only in casts, which in every case appear to be very strongly phosphatic. One of the layers of this section is a sandy limestone containing a large percentage of phosphoric acid (see details below). These beds appear in a small bluff at the mouth of Tear Up Creek, above Bridgeport, which has been studied by Mr. Johnson; also in localities recently examined by Mr. Langdon and myself, viz, in the bluff at the old Canton landing; on Foster's Creek, in Gee's Bend; near Snow Hill, Wilcox County, and

Minter, Carlowville, and Richmond, in Dallas County; the four last named localities were also visited by Mr. Johnson in 1883.

Fourth. From sixty to one hundred feet of sand, with indurated bands of calcareous sand passing through it. These hard, projecting, sandy layers are usually filled with the shells of large *Exogyra costata* Say and *Gryphæa mutabilis* Mort. The thickness of these sandy beds, which apparently immediately overlie the Rotten Limestone, has not yet been accurately determined, but we see some fifty feet or more of them at Prairie Bluff.

Prof. A. Winchell[1] considers the rock at the base of Prairie Bluff as the topmost of the Rotten Limestone formation, and if this supposition be correct we have the complete section of the Ripley formation. We were, however, unable to satisfy ourselves of the identity of any of the rocks at Prairie Bluff with the Rotten Limestone, though we are convinced that the top of the latter formation does not lie far below the lowermost of the Prairie Bluff strata, since Rotten Limestone appears in the hills near the river a short distance above Prairie Bluff.

SECTIONS OF THE RIPLEY FORMATION.

In the subjoined sections and in the figures on Plate XIX we have given in detail the characters of the strata making up these subdivisions of the Ripley formation. These sections are given in descending order, that is, beginning with that one which shows the uppermost of the strata, and in the figures of Plate XIX the equivalence of the several sections is indicated as nearly as it can be made out. In most cases the equivalence is very clearly seen.

Near Palmer's Mill, on Pine Barren Creek, in the eastern part of Wilcox County, Mr. Johnson in 1883 obtained the following satisfactory section showing the actual contact of Tertiary and Cretaceous strata. The locality was also visited by myself in 1885, as mentioned above.

(*a*) ***Pine Barren section.*** *(Plate XVIII, Fig. 1, p. 167, and Plate XIX, Fig. 1, p. 171.)*

1. Hard, grayish white limestone, characterized by great numbers of a large *Nautilus* (*Enclimatoceras Ulrichi* White), and hence designated by us as the "Nautilus Rock" .... 10 feet.
2. Calcareous sands forming the basis of the sandy prairies of the vicinity .... 6 feet.
3. Hard, yellowish white, crystalline limestone, sandy in places and filled with red specks. Highly fossiliferous, a *Turritella*, closely related to *T. Mortoni*, being the chief fossil, along with a *Cardita*, two or three species of coral, and numerous oysters. This is one of the most persistent of the lower Tertiary rocks towards the eastern part of the State .... 8 feet.
4. Yellowish, micaceous sands, with Cretaceous fossils .... 55 feet.
5. Bluish gray, calcareous sands, with one or two very prominent hard ledges 4 feet apart, and two or three smaller ledges of similar character. Thickness seen at Palmer's Mill .... 15 feet.

[1] Proc. Am. Assoc. Adv. Sci., Vol. X, Part II, p. 91, 1856.

In this section the lowest Tertiary bed is No. 3 and the uppermost Cretaceous No. 4, as is very clearly shown by the included fossils of each, and as the two are in direct contact there can be no question of their relations.

Bridgeport.— On the way from Camden to Bridgeport the road descends a long clay hill, in which the clays of the Black Bluff horizon form the surface (see Pine Barren section, under the Tertiary, Plate XVIII). At the foot of the hill is the yellowish white, crystalline limestone, No. 3 of the preceding section, and below that yellow, micaceous sands to the landing. . At the Bridgeport Landing these yellow sands form the upper part of the bluff, though their whole thickness is not seen in the immediate bluff of the river, but may be seen at the base of the hills immediately back of the river bluff.

The section at Bridgeport is as follows:

(*b*) *Section at Bridgeport Bluff, Alabama River.* (*Plate XIX, Fig. 2, p. 171.*)

1. Yellowish, clayey sands, probably reworked....................10 feet.
2. Coarse, yellow sands....................10 feet.
3. Laminated, gray clays....................1 foot.
4. Projecting ledge of sandy clay of dark gray color....................1 foot.
5. Dark gray, nearly black, sandy, and in some parts micaceous clays, in beds about 3 feet thick, separated by hard projecting ledges of sandier material and of lighter color and averaging 8 to 10 inches in thickness....................22 feet.
6. Projecting ledge of light colored, sandy material, forming a pretty firm sandstone. This ledge breaks off in cuboidal blocks, which roll down and cover the slope below it....................18 inches.
7. Dark gray clays....................3 feet.
8. Projecting sandy ledge....................1 foot.
9. Dark, sandy clays, with two or more harder ledges, down to the water level..10 feet

The ledge No. 6 makes a very prominent mark along the face of the bluff, as it is more persistent, harder, and more rock like than the others. No distinct and well defined fossils were found at this place in the micaceous clays, but in one or two of the harder ledges below No. 6 were found a few friable shells of Ostrea, one *Pecten quinquecostatus* Sow., and a few indistinct impressions of other forms, two of which, if Mr. Johnson is not mistaken as to their characteristics, he was enabled at Eufaula to identify as *Nautilus Dekayi* Mort. and *Placuna scabra* Mort.

Canton Landing.—A short distance below Bridgeport there is an exposure of Cretaceous rocks at the old Canton Landing and in the hill which comes down nearly to the river bluff at that place. This locality was examined by Mr. Langdon and myself in the summer of 1885. It presents the following:

(*c*) *Section at the old Canton Landing, Alabama River.* (*Plate XIX, Fig. 3, p. 171.*)

1. Yellowish gray, calcareous, clayey sands in beds 3 to 5 feet thick, separated by harder projecting ledges of somewhat sandier material averaging perhaps a foot in thickness....................100 feet.

   The hard ledges named have a tendency to flake off on weathering into sheets as wide as the hand. They often also break off into fragments which are of very

irregular shape and of rough surface. All these beds make up the hill, appearing at intervals through the overlying débris, but no continuous section is exposed. In some places the clayey sands lying immediately below one of the hard ledges have the bluish black color which characterizes the whole of the lower part of the Bridgeport bluff, with which there seems to be very little doubt that these are identical.

2. Yellowish, calcareous, sandy clays like the preceding, with a hard, sandier ledge above and below, making top of immediate bluff of the river ....10 feet.
3. Bluish, micaceous clays, the counterpart of those at Bridgeport, with two or more indurated ledges ....12 feet.
4. Light gray, calcareous sands, with an indurated ledge of nearly pure sandstone at the base. The upper part of this bed is disposed to form rough, indurated masses holding phosphatized shell casts and phosphatic nodules ....6 feet.
5. Bluish gray, sandy clays, much more clayey than the preceding bed, about 5 feet in thickness, passing below into a more sandy bed 3 feet thick, containing numerous shell casts and nodules ....8 feet.
6. Bluish, argillaceous limestone, containing great numbers of *Exogyra costata* Say, *Gryphæa mutabilis* Mort., and phosphatized shell casts .... 3 feet.
7. Bluish, calcareous sands containing many well preserved shells, prominent among which is a *Spondylus*, *Pecten quinquecostatus* Sow., together with phosphatized casts of *Nautilus Dekayi* Mort., turreted shells, &c. This bed goes down to water level ....3 feet.

At this bluff there is a very distinctly defined fault, where some fifty yards of the face of the bluff have slipped down a distance of five or six feet. The lines of fault on each side of this piece are marked by broken fragments of the beds or so-called "fault rock" (see Fig. 1, p. 132).

In this section, beds Nos. 2 and 3 are entirely similar in mineral composition and appearance to part of the Bridgeport bluff, and the overlying beds are also similar in composition, though of much lighter yellowish color, which is in all probability due to their greater degree of exposure to the oxidizing action of the weather. This bluff is only a mile or so distant across the strike of the rocks from Bridgeport, and there seems to be no reason for doubting that the bluish, micaceous clays and sands of Bridgeport are identical with the yellowish, sandy clays with indurated ledges which form the upper members of the Canton section. The beds numbered from 4 down we consider the same as those appearing at the top of the bluff at Prairie Bluff, to be presently described.

Foster's Creek.—The beds above described at Canton landing continue across the bend lying to the east and known as Gee's Bend, where they may be seen in the banks of Foster's Creek, on John H. Pettway's land.

(*d*) *Section on Foster's Creek.* (*Plate XIX, Fig.* 4, *p.* 171.)

1. Yellowish, calcareous, clay soil supporting a vegetation almost exclusively of cedars.
2. Dark gray, sandy, micaceous clays like those at Bridgeport landing, in beds of 5 to 6 feet thickness, separated by harder ledges of lighter colored and sandier material ....30 feet.

   In the lower part of these beds were collected by myself some of the small Gryphæas, probably *Gryphæa vomer* Mort., first seen by us at Moscow, on the Tombigbee River.

3. Cream colored, impure limestone, glauconitic, holding some phosphatized shell casts ....5 feet.
4. Ledge of coarse grained, calcareous sandstone ....2 feet.
5. Bluish, clayey limestone, no fossils at the top, but filled in its lower parts with fossils which are in many instances only the phosphatized casts of the shell. Among the forms collected here we have identified the following: A *Spondylus*, same as that at Canton; *Gryphæa mutabilis* Mort., *Exogyra costata* Say, *Scaphites Conradi* Mort., *Nautilus Dekayi* Mort., &c ....20 feet.
6. Dark brown, crystalline, phosphatic limestone ....1 foot.
7. Yellowish white limestone down to water ....1 foot.

In another part of the same plantation, on what is called Livingston Hill, the phosphatic limestone and accompanying rocks may again be seen. From the geographical position of the beds represented in the above section, there is every reason to think that they underlie the visible portion of the bluff at Bridgeport. The identity of the lower 20 feet or so of this and of the Canton section is sufficiently clear.

Tear Up Creek.—A few miles above Bridgeport, at the mouth of Tear Up Creek, Mr. Johnson obtained in 1883 a good section of the beds underlying those of the Bridgeport bluff and was able to trace the connection between the two.

(e) *Section at the mouth of Tear Up Creek.* (*Plate XIX, Fig.* 5, *p.* 171.)

1. Ferruginous, sandy marl full of Cretaceous fossils ....3 feet.
2. Very firm, white limestone, no fossils seen ....6 feet.
3. Firm limestone, with a few fossils ....2 feet.
4. Sandy, calcareous beds, with fine *Ammonites* ....4 feet.
5. Sandy, indurated limestone forming a broad ledge ....1 to 2 feet.
6. Argillaceous limestone, with *Exogyra costata*, &c ....8 feet.

The fossils of this bluff are plainly Cretaceous and resemble the finest of those occurring at Prairie Bluff. There is good reason for thinking that most of the fine specimens of the old Tuomey collection labeled "Bridgeport" have come from this locality (L. C. J.). The dark, micaceous clays of Bridgeport are easily recognized in the bed of Tear Up Creek between its mouth and its source under McNeill Mountain, as shown in Plate XIX, Fig. 5. As has already been pointed out, they are seen also in the banks of Pine Barren Creek, at Palmer's Mill. The fossiliferous portion of this bluff is undoubtedly equivalent to the fossiliferous beds occurring on Foster's Creek and at Canton Landing, above described, as also to those at the top of the Prairie Bluff, given below.

During the summer of 1886 Mr. Langdon and myself went in a skiff from Bridgeport to Prairie Bluff and saw no Rotten Limestone in any of the river bluffs, all these exposures representing the Bridgeport and Prairie Bluff strata only.

The principal exposures are the following: From Bridgeport the bluff extends about a mile down the river, and then after a barren

stretch of two miles or more come the bluffs at the old Canton Landing described above, and below that the following:

(f) Section four or five miles below the old Canton Landing, Alabama River.

1. Sandstone ledge, fossiliferous, yellowish, and wearing into very irregular shapes, 1 to 1½ feet.
2. Highly fossiliferous, blue sand, becoming light gray below, containing *Ostrea larva*, *Exogyra costata*, *Turritella*, &c., very much resembling specimens from Eufaula .... 5 to 6 feet.

Two hundred yards down the river other underlying beds are to be seen, as follows:

3. Sandstone ledge .... 1 to 1½ feet.
4. Light colored sands, no fossils observed .... 20 feet.

At an old abandoned landing just above Mixon's we get a very good section, as follows:

(g) Section near Mixon's.

1. Yellow sands making top of the bluff back of the immediate river bank, at least 30 feet exposed, but apparently forming the whole slope of 60 feet .... 60 feet.
2. Blue, micaceous sands, with the same fossils as No. 2 of the preceding section, 6 to 8 feet.
3. Sandstone ledge .... 1 to 1½ feet.
4. Light colored sands .... 30 feet.
5. Hard sandstone ledge .... 1 foot.
6. Blue, micaceous, sandy clays (few fossils) .... 10 feet.

A mile or two above Prairie Bluff there is a high bluff very much resembling that at the former locality. The strata are undulating, at the lower end of the bluff dipping down stream at the rate of 1 foot in 10, at the upper end lying nearly horizontal. The beds here are as follows:

(h) Section one mile above Prairie Bluff (Rocky Bluff), Alabama River.

1. In the cliff just back of the immediate bluff of the river there are about 40 feet of strata, light colored, calcareous sands, with indurated bands, as at Prairie Bluff .... 40 feet.
2. Dark blue, sandy, micaceous clays, with a few fossils, chiefly Anomias .... 20 feet.
3. Hard, yellow, sandy ledge, the broken pieces of which cover the slope of No. 4. It dips below water at the lower end of the bluff .... 1 foot.
4. Grayish, fossiliferous sands, full of shells of *Pecten quinquecostatus*, which, however, are very friable .... 8 feet.
5. Hard, yellowish, sandy ledge like No. 3 .... 1 foot.
6. Bluish gray, calcareous sands, with some fossils .... 10 feet.

In all these bluffs the indurated sandstone ledges are of very irregular thickness and lateral extent and are probably only local deposits in the regular strata or local indurations of the sands.

Prairie Bluff.—This locality has been visited by Professor Tuomey, Professor Winchell, and others.[1] We have very little to add to their descriptions, except to point out the probable equivalences of the beds

[1] Described in First Bien. Rep. Geol. Ala., 1850, and Proc. Am. Assoc. Adv. Sci., Vol. X, Part II, p. 90, 1856.

occurring here with those just described. The bluff shows the following:

(i) *Section at Prairie Bluff, Alabama River.* (*Plate XIX, Fig. 6, p.* 171.)

1. Bluish limestone containing *Exogyra costata*, *Gryphæa mutabilis*, and great numbers of shell casts, which are mostly phosphatized. This limestone has two hard ledges passing through it. Professor Winchell gives 6 feet as the thickness of this limestone, but we include with it some overlying fossiliferous, sandy beds and make the thickness[1] .... 20 feet.
   Among the forms recognized in casts or otherwise from this stratum may be mentioned *Gryphæa convexa*, *Placuna scabra*, *Scaphites Conradi*, and *Nautilus Dekayi*. Besides these there are very many other turreted shells not fully identified. The association is the same as at Canton Landing, Foster's Creek, Tear Up Creek, &c.
2. Sandy beds, with bands of hardened sand passing through them; these harder ledges are usually fossiliferous, the commonest forms being *Exogyra costata* and *Gryphæa mutabilis*. These sands form all the lower part of the bluff. .50 to 60 feet.

The upper sandy beds contain great numbers of *Ostrea falcata* Mort. The lower beds are of dark blue color, but they bleach out to nearly white sand where they come to the top of the bluff, a short distance up the river from the landing.

The dip of the strata at Prairie Bluff is very considerable, being as high as 300 to 350 feet to the mile. Between Prairie Bluff and Rehoboth the hills are formed of the strata overlying the limestone No. 1 of the section. These are yellowish, micaceous sands, in beds 5 to 6 feet in thickness, separated by sandy ledges, and in all respects similar to the upper 100 feet of the section at the old Canton Landing. In structure and general appearance they are like the dark colored, sandy clays of Bridgeport, but the color is much lighter, due, as we believe, to the more complete oxidation of the materials. In these sands there are, in some localities, great numbers of irregular calcareous concretions. All the shell casts occurring in the upper calcareous part of Prairie Bluff,

[1] In the summer of 1886 Mr. Langdon gave this bluff a closer examination. He subdivides that part of No. 1, immediately above the sands, as follows:

1. Shaly, calcareous sands, yellowish gray on weathered surface; contains a seam of phosphatic greensand at the top, immediately underneath the warehouse..4 feet
2. Pseudo-Rotten Limestone, i. e., calcareous clay..........3 feet
3. Shell conglomerate..........3 to 4 feet
4. Light colored sands &c., No. 2 of the section in the text above.

Mr. Langdon makes the additional important observation here that the very rapid dip down stream is confined to the sandy strata No. 4, and is not shared by Nos. 2 and 3, which half a mile below the warehouse are only about ten feet nearer water level than at the warehouse, while the uppermost indurated ledge in the sands No. 4 dips below the water within a distance of 200 yards, a descent of some 40 or 50 feet. This observation would show an unconformity between the calcareous and the sandy parts of the strata at Prairie Bluff.

Our discovery of the phosphatic greensand here fixes its position in the geological scale. The bed at Coatopa, in Sumter County, seems to have a similar position, but it appears now probable that there are at least two of these phosphatic greensands in the Ripley formation.

together with the calcareous sandstone which is included in the limestone, are very strongly phosphatic, as has been shown by the recent investigations of the Geological Survey of Alabama.

In the foregoing sections the calcareous and fossiliferous parts, about 20 feet in thickness, appearing at the mouth of Tear Up Creek, on Foster's Creek, at the base of the Canton Bluff, and at the top of Prairie Bluff are, we think, the same; for, though there seem to be slight differences in the succession of the different materials which constitute these beds, these differences are in many cases due to differences in the groupings. The general impression made upon the mind in inspecting them is that they are identical; they contain the same fossils and in the same state of preservation; they hold strata of sandy limestone, or, rather, of calcareous sandstone which is very highly phosphatic; in some instances, where analyses have been made, they hold from 10 to 15 per cent. of phosphoric acid. In all cases they are overlaid by micaceous, clayey sands, traversed by indurated bands of similar, but rather more sandy, material. These overlying beds differ sometimes conspicuously in color, which at Bridgeport, near the water level, is a dark blue, while on the hills back of the old Canton Landing and back of Prairie Bluff the color is a yellowish gray. This difference can be accounted for by differences in degree of oxidation, for where the color at the surface is yellow we have noticed that upon digging into the beds a few inches the dark color may be seen in most cases. In our minds there is no doubt of these equivalences. Prof. A. Winchell is of opinion that the lower beds of the Prairie Bluff section belong to the Rotten Limestone, but we were unable to discover anything there which we could identify with the Rotten Limestone. There is no doubt, however, for reasons above given, that the Rotten Limestone is not far below the lowest of the Prairie Bluff sands.

Moscow.—On the Tombigbee River we have seen only one locality where the strata of this division of the Cretaceous appear, and that is at Moscow, a mile or two above Black Bluff, already described.

(*j*) *Section exposed at Moscow and below, Tombigbee River.* (*Plate XIX, Fig. 7, p.* 171.)

1. Black, shaly clay, devoid of fossils, but containing a few rounded, concretionary masses like fucoids. This stratum appears below the Moscow Landing and in the principal stratum at the mouth of Sucarnochee River. Thin layers of calcite lie upon this clay, having been weathered out from between the layers of clay, in all..6 to 8 feet.
2. Dark blue, shaly, argillaceous limestone, with thin, projecting ledges of harder material, 10 to 12 feet thick near Moscow, but down the river thickening up to ....20 or 30 feet.
3. Thin ledge made up almost entirely of the shells of the small Gryphæa (*Gryphæa vomer*), noticed also at Foster's Creek, in Gee's Bend..............8 to 12 inches.
4. Hard, white, argillaceous limestone, with *Exogyra costata, Gryphæa mutabilis,* &c...10 feet.[1]

[1] Near the landing this bed is not less than 25 feet.—E. A. S.

This stratum is indurated near the top, forming a hard ledge which is highly fossiliferous, containing Exogyra, Gryphæa, *Nautilus Dekayi*, Baculites, and univalve shells in phosphatized casts. Many of these casts are covered with little lumps of reddish, phosphatic, clayey material, which has replaced the whole of the original matter of the shells. Casts of this kind have been noticed in the strata of this horizon all across the State to Barbour County and seem to be quite characteristic.

In this argillaceous limestone there is, near the top, a very irregular, hard ledge consisting in the main of comminuted shells embedded in a sandy matrix. This ledge is very variable in thickness, ranging from a mere line up to 10 feet, and is not conformable with the rest of the strata, but appears to form irregular concretionary or segregative masses in the limestone. It contains a considerable percentage of phosphoric acid. A similar phosphatic sandy bed appears at top of Prairie Bluff, at the base of the Canton Bluff, and in the bank of Foster's Creek, above described.

The dip of the strata at Moscow is very rapid down the stream, and at the same time irregular, being in places as much as 350 feet to the mile, in which respect it agrees with the dip at Prairie Bluff. It is to be remarked that the dip of the Tertiary beds nearest to these two sections, viz, Black Bluff on the Tombigbee and at Midway and at Matthews's Landing on the Alabama, is very much less, being only about thirty to thirty-five feet to the mile. The dip of the Ripley beds, indeed, especially near the top, seems to be considerably greater than that of the underlying Rotten Limestone and other Cretaceous strata.

In the summer of 1886 Mr. Langdon and myself made a more careful examination of the bluffs between Moscow and the cut off, just above the mouth of Sucarnochee Creek, a distance of a mile or two. We found the strata not only strongly undulating, but in six or eight places very distinctly faulted, with a displacement of perhaps ten feet maximum.

Good photographs were obtained of two of these faults, and diagrams were made of several others. A very careful measurement of the thicknesses of the several strata exposed here confirms the estimates above given in the Moscow section, except that the black clays may be a little thicker, and the white, argillaceous limestone, No. 4, is at least 25 feet thick at the landing. Our former measurement was made a short distance below, where only 10 feet of it were seen.

The pockets of cross bedded sandstone which are noted as occurring at irregular intervals in this limestone are of very limited extent and of varying thickness. In one or two instances they have been broken by the faults above noted. (See Plate X, p. 133.)

That which we find most difficult of explanation at Moscow is the [illegible] from the undoubted Ripley limestone, which appears to be the [illegible] horizon with the beds at the old Canton Landing, in Gee's Bend, [illegible]th of Tear Up Creek, &c., to the black clays of the Black

Bluff section (Tertiary), without any show of the Bridgeport sandy clays and the Nautilus and the Turritella rocks. And as the black clays and the Cretaceous limestone are in actual contact, visible to the eye, we cannot explain the failure of these beds to appear here, by interruptions in the continuity of the river bluffs. It is possible that the black clays may be the representatives of the Bridgeport beds, but it is not probable, for the reason that they are lithologically identical with the clays of Black Bluff, which is hardly more than a mile distant.

For the sake of greater completeness, we give below a few sections obtained in the southern part of Dallas County where the Ripley beds are exposed. These localities have acquired a practical interest from the circumstance that they include a bed of phosphatic greensand which has been used with profit upon the soil as a fertilizer. In addition to this greensand bed, there is also a sandy, phosphatic limestone which may some day be utilized, since it holds a very considerable percentage of phosphoric acid.

Snow Hill to Minter.—The town of Snow Hill occupies the summit of a long ridge, at the southern end of which the Nautilus and the Turritella rocks of the lowermost Tertiary form the surface, while at the northern end of the ridge the underlying yellow sands are the surface materials. Descending this ridge towards the north, one passes over yellowish gray, micaceous sands, alternating with hard, sandy ledges which flake off under the action of the weather. These strata are the same as those exposed on the hillside near the old Canton Landing and on the hill north of Prairie Bluff. Near the residence of Mr. W. S. Purifoy, a mile or so from Snow Hill, we see some fifty or sixty feet of these sands and shales overlying a bed of phosphatic greensand three feet or more in thickness. The section here exposed is the following:

(*k*) *Section near W. S. Purifoy's, near Snow Hill.*

1. Yellowish, micaceous sands, in beds four or five feet thick, separated by ledges of sandier material, which flakes off in weathering....................50 to 60 feet.
2. Phosphatic greensand, holding concretions of white carbonate of lime and a good deal of soft, white lime..4 feet.

   This greensand contains from 1.5 to 2 per cent of phosphoric acid. It lies very favorably at the foot of the hill, and at the level of the cultivated fields, and can be dug and spread upon the land with very little trouble or expense.
3. Hard, reddish or yellowish, phosphatic limestone, forming very irregular, concretionary masses..1 foot.
4. Yellowish, calcareous clays containing great numbers of large *Exogyra costata, Gryphæa mutabilis*, &c..20 feet.
5. Impure, argillaceous limestone, containing numbers of the shells above named, 10 to 15 feet.

This greensand has been tested practically by Mr. Purifoy, and with the most flattering results.

On Col. N. H. R. Dawson's place, adjoining Mr. Purifoy's on the north, the same beds are to be seen, together with some still lower. Below the greensand bed there are some sixty to seventy feet of calcareous, sandy

beds with hard ledges, and near the base of the series an impure limestone weathering into calcareous clays, in which are embedded great numbers of *Exogyra costata*, *Gryphæa mutabilis*, and phosphatized shell casts, prominent among which are *Nautilus Dekayi*, and *Scaphites Conradi*. This shell deposit lies about six feet above a bed of hard, silicious, phosphatic limestone or calcareous sandstone, which is the lowest of the strata here exposed.

Carlowville.—At Carlowville there is substantially the same section.

(l) Section at Carlowville, Dallas County.

1. A bed of phosphatic greensand holding much lime, in small concretions and in soft lumps easily crushed between the fingers....................4 feet or more.
2. A clayey, glauconitic limestone, which has been quarried for the purpose of building culverts on the railroad..3 feet.
3. Yellowish, calcareous, sandy shales with hard sandy ledges. The color of this material, where wet and not exposed to the weather, is dark blue like that at Bridgeport..60 feet.
   In the lower part of this there is an impure, argillaceous limestone which holds a great number of the two shells above named, together with casts (phosphatized) of others.
4. Hard, coarse grained, silicious limestone or calcareous sandstone..........2 feet.

Richmond.—A few miles southwest of Richmond, on the land of Dr. J. P. Keyser, we get a more complete section embracing beds which overlie the preceding, viz:

(m) Section 3 miles southwest of Richmond, Dallas County.

1. Sandy shales, hardening into a shaly sandstone, forming a conspicuous ledge along the hillsides. This is underlaid by about 20 feet of calcareous sandy clays, similar to those near old Canton Landing..............................20 feet.
2. Calcareous, sandy ledge somewhat like the preceding, but perhaps more calcareous. This also overlies a series of calcareous shales, 35 feet or more............40 feet.
3. Bed of phosphatic greensand, with lumps of soft white limestone and concretions of lime..4 feet.
4. Impure, clayey, glauconitic limestone, making a shelf or ledge around the hillsides..3 to 5 feet.
5. Calcareous shales interstratified with beds of sandier material which form projecting ledges. These beds correspond in appearance to those forming the hill back of old Canton Landing, and where less exposed to the weather they still retain the dark blue color which is characteristic of them at Bridgeport. They hold the usual fossils in their lower strata, and in weathering give rise to the formation of a calcareous, clayey soil..60 to 70 feet.
6. Hard, silicious limestone, coarse grained and phosphatic, appearing near the water level at base of the hills...3 feet.

We have not yet given these localities the close examination which [illegible]ould enable us to say with certainty what their equivalents are; yet, [illegible]m the position of the fossiliferous, impure limestone containing *Exo*-[illegible]*ra costata*, *Gryph*[illegible]*bilis*, and the phosphatic shell casts above [illegible]amed, it seems [illegible]ble that this greensand lies some 50 feet or [illegible] the [illegible] beds of old Canton Landing and of Prairie [illegible] the phosphatic, silicious rock at

the base of the preceding sections, we have seen at other localities a yellow sand which is traversed by bands of silicious sandstone precisely as is the case at Prairie Bluff, so that we have very little doubt of the equivalence, although it is not certainly made out.[1]

These Upper Cretaceous rocks belonging to the Ripley formation have recently acquired a new interest from the circumstance that they are throughout the State very generally impregnated with phosphoric acid, often to such a degree as to render them available as materials for the manufacture of fertilizers. Thus the rock at Moscow and westward to Coatopa and Livingston and thence traced to Shuqualak, Miss., by Mr. Johnson, has been found to be phosphatic, and the same is true of the hard ledges of limestone rock occurring in the Canton bend, and thence eastward to Minter, and on to Fort Deposit, and thence to Chunnenugga Ridge and Union Springs. The occurrence and the characters of these phosphatic rocks will be more fully described at another place.

§ 2. THE ROTTEN LIMESTONE.

The next subdivision of the Cretaceous group, viz, the Rotten Limestone, extends for many miles along both the rivers, and, assuming a uniform dip of 25 to 30 feet to the mile, its thickness cannot be much less than 930 to 1,200 feet. The rock is of comparatively uniform composition, being a gray to bluish colored, argillaceous limestone, traversed at intervals by beds of purer limestone which is at the same time usually a little harder in texture. In some places the material is a dark bluish clay marl, in appearance not altogether unlike some of the blue or black clays at the base of the Tertiary group. The fossils of the Rotten Limestone are principally Exogyra, Gryphæa, and Ostrea, but in the upper and lower parts other forms become more abundant, forming transitions to the overlying and underlying subdivisions.

The best general view of the strata of the Rotten Limestone is afforded by the record of a boring for an artesian well at Livingston, Sumter County. The town is situated on the line of junction of the Rotten Limestone and Ripley formations, and the boring, therefore, passes through the whole of the former into the underlying Eutaw greensands. The boring was made from December, 1854, to March, 1857, and the record was carefully kept by Dr. R. D. Webb. The thickness of Rotten Limestone proper penetrated by this boring is 930 feet, the underlying sands and greensands belonging probably, for the most part, to the next division. The uppermost 20 feet are certainly in part drift and probably in part Ripley formation, though there are no fossils to decide the matter definitely.

[1] A bed of phosphatic greensand was discovered in 1886 by Mr. Langdon and myself at Prairie Bluff just overlying the limestone strata. Whether this is the same as the bed above described or a different one, we are not yet prepared to say.—E. A. S.

Section of the Rotten Limestone at Livingston, Sumter County. (*See Plate XXI, Column 4, p. 183.*)

	Materials.	Depth in feet.
1	Sandy loam, 1 foot	1
2	Coarse, dry sand, stratified, 12 feet	13
3	White quicksand (had to be curbed), 7 feet	20
4	Soft, rotten, blue limestone, thickly set with shells and containing iron pyrites, 180 feet	200
5	White limestone, harder than the preceding, with very few if any shells or pyrites, 50 feet	250
6	Hard, blue limestone, so hard that the auger cuts it with difficulty, clear of shells and pyrites, 7 feet	257
7	Bluish white limestone, not so hard as the preceding, clear of shells and pyrites, 68 feet	325
8	Very hard, white limestone, 55 feet At 330 feet, passed through a stratum of oyster shells from which a specimen very much resembling an egg was brought up.	380
9	Light blue limestone, not so hard as No. 8, but harder than No. 4, 47 feet	427
10	Bluish brown rock, filled with small shells. In this there was more sand than in the blue or white varieties of rock, 58 feet	485
11	Hard, white rock, 105 feet	590
12	Soft, reddish brown rock, 2 feet	592
13	Soft rock of deep blue color, 20 feet	612
14	Brownish blue rock, moderately soft, 78 feet	690
15	Hard, gritty, bluish colored rock, so hard that it had to be drilled, 6 or 8 inches	630
16	Dark bluish colored rock, easily cut by auger, 10 feet	700
17	Soft, whitish limestone, with occasional slight change in hardness and color, 250 feet	950
18	Hard sandstone, 6 feet	956
19	Sand, in which, at 964 feet, a small stream of water was reached, which ran feebly from the top of the well, 10 feet	966
20	Sand rock, 1 foot	967
21	Coarse greensand, in which a larger stream of water was reached at 1,005 feet depth, 38 feet	1,005
22	Sandstone, 2 feet	1,007
23	Greensand, 25 feet	1,032
24	Sandstone, 2 feet	1,034
25	Coarse greensand, 18 feet	1,052
26	Flint rock (crystallized), 1 foot	1,053
27	Very fine greensand, 9 feet	1,062

In this greensand the well was stopped at a depth of 1,062 feet.

In the following notes are given the characters of the Rotten Limestone as shown in a few prominent bluffs along the rivers, without any attempt to fix absolutely their position in the vertical scale of the boring.

The great degree of uniformity in the lithological characters and fossil contents of the different parts of the Rotten Limestone makes it impossible as yet to give the precise place in the vertical section of its ex-

posures described below, with the exception of those which include the phosphatic greensands immediately below the limestone proper. We have, therefore, not attempted to represent the main body of the limestone except in the single plate illustrating the boring at Livingston; but in Plate XX we have given several figures illustrating the contact of the Rotten Limestone with the underlying, sandy beds.

EXPOSURES OF ROTTEN LIMESTONE.

About eight or nine miles above Moscow landing there is at Barton's Bluff an exposure of about sixty feet, consisting of dark bluish, clayey limestone, or perhaps better described a blue marl, with several harder ledges projecting from the face of the bluff. These ledges hold a good many fossils, the principal forms being *Ostrea falcata* in the upper ledges and large Gryphæa and Exogyra in the lower ones. These dark, clayey, limestone bluffs continue up the river to within nine miles of Demopolis. They are probably represented by No. 4 of the boring.

On the Alabama a similar material makes the bluff at Lexington Landing, and it holds also a large number of shells, especially those of Exogyra and other oysters.

At Demopolis the bluff is made of a very compact, light blue or gray limestone, which does not seem to be very highly fossiliferous. A similar limestone makes the bluffs for several miles down the river, nearly to Barton's Bluff, where, as already stated, it is more argillaceous and darker in color.

On the Alabama the counterpart of the Demopolis Bluff may be seen at Elm Bluff and at White Bluff.

The same rocks may also be seen on the Upper Tombigbee River (above the mouth of the Tuscaloosa) at Jones's Bluff, where the railroad bridge crosses the river.

Underlying the Demopolis limestone there is a stratum of undetermined thickness of a tolerably pure limestone of light yellow color, filled with concretionary lumps, cylinders, &c., of clay. When this clay washes out it leaves the limestone perforated in every direction, which circumstance is referred to in the name "bored rock." Below Arcola this bored rock is quite thick, and has bedding planes two or three feet apart, which cause the rock to break up into large cubical blocks.

At Arcola and at Hatch's Bluff, on the Tuscaloosa, the bored rock is near the top of the bluff, and underlying it is softer and crumbling Rotten Limestone of the usual character. The bored rock has sometimes been burned for lime, and its outcrop may be followed westward as far at least as Sherman, in Sumter County. It forms a rocky ridge wherever it comes to the surface.

The limestone underlying the bored rock for many feet is tolerably uniform in composition and resembles that of the Demopolis Bluff, except that it is, if anything, rather more argillaceous and less compact,

being rather a white, calcareous clay than a limestone. There is nothing of interest to record at any of the bluffs of the river from Hatch's Bluff up to Wolf's Bluff, just above Cowan's Landing.

Here come in the strata, still better exposed higher up at Erie and at Choctaw Bluff, which form the transition between the Rotten Limestone and the sands of the Eutaw formation, and which probably represent the Tombigbee Sand group of Dr. E. W. Hilgard, if this group has its counterpart on the Tuscaloosa River.

Characteristic fossils of this horizon appear to be certain reptilian bones, Mosasaurus, the curious Hippurites, teeth of sharks, and large palatal teeth (*Ptychodus Mortoni* and others).

The lowermost strata of the Rotten Limestone (calcareous clays) also contain many of these fossils, and in addition to those mentioned, shells of Inoceramus in great numbers and of great size. These shells are of fibrous texture, the thickness of the shell (half an inch or less) forming the length of the fibres. In consequence of this structure the shells are very fragile and it is impossible to take them out unbroken except by removing a block of the matrix rock with them.

In no localities have I seen them in greater numbers and of larger size than in the long bluff at Fairfield, on the Tombigbee River, in the southern part of Pickens County, and in the fields back of House Bluff, on the Alabama River, in Antauga County. In the former place they are perfectly preserved, and many of them are more than a foot in diameter.

Near House Bluff they are seen in the old fields, associated with Leiodon bones, sharks' teeth, and phosphatic greensands. In the weathering of rock they break into fragments which, though slightly separated, retain their relative position and preserve the outline of the shell. In many cases these fragments cover a space three feet in diameter, indicating the size of the shell as at least two feet in diameter.

These would probably form the first of the transition beds above mentioned.

On the Alabama River these beds make their appearance above the latitude of Selma at Cunningham's and House Bluffs. Inasmuch as their paleontologic relations have not yet been determined and as they are more closely related in lithologic character to the Eutaw, we have thought it best to combine them with the latter formation in our description. The first five sections in the next division exhibit the Rotten Limestone in connection with the next underlying beds.

§ 3. THE EUTAW FORMATION.

As noted above, the sandy, fossiliferous strata lying beneath the argillaceous and calcareous rocks whose lithologic character is so well defined by the name of Rotten Limestone are referred by us to the Eutaw formation. In striking contrast with the Rotten Limestone, this series of deposits consists of sands and clays with little or no calcareous

matter except in the uppermost 25 or 30 feet spoken of above as forming a transition between the Rotten Limestone proper and the sands of the undoubted Eutaw.

This upper member of the Eutaw formation consists at the summit of a bed 5 feet in thickness of indurated, calcareous sands, with numerous fossils and irregularly shaped nodules of nearly pure phosphate of lime, together with many highly phosphatized shell casts, and in addition the sand itself is very generally phosphatic. Below this bed there are 15 feet of sand with comparatively few fossils, except in a thin layer of compacted shells at the base and in two or three similar shell layers dividing the sand at different horizons. These shell beds are also usually phosphatic. Beneath the lowest comes a bed of greensand 6 to 8 feet in thickness, which is distinguished by its high percentage (5 per cent. and above) of phosphoric acid. These phosphatic and calcareous beds have been less closely examined on the Alabama River than on the Tombigbee, where they appear to be somewhat thicker.

The bulk of the lower and principal member of the Eutaw formation consists of cross bedded sands, with subordinate beds of pebbles and of thinly laminated clays with sandy partings in many alternations. The exact sequence of these beds is known only for about 80 or 90 feet below the phosphatic strata above mentioned. (See profile at the House Bluff, Alabama River, Pl. XX, Fig. 5, p. 175.)

The most striking peculiarities of the various beds of the lower member of the Eutaw formation are found in the abrupt changes which they undergo in both the vertical and horizontal directions. The dark gray, laminated clays with sandy partings seen at Finch's Ferry, Tuscaloosa River, may also be seen farther up the river at Semple's Bluff and at Brown's Bluff, and with nearly the same characters in all three localities. With this exception, however, I know of none of the Eutaw beds which preserve their characters with anything like uniformity for more than a few rods. Laminated clays pass into cross bedded sands or rather are replaced by them; cross bedded sands thin out abruptly, as if forming lenticular masses; the pebble beds thicken up and thin down rapidly within a few yards' distance; and indeed it is impossible to follow any of the beds with certainty from one end of a long bluff to the other, and it would be well nigh impossible to get two vertical sections of a bluff, 100 yards apart, which would exhibit the same sequence of materials. Two examples will illustrate my meaning. At Stave Bluff, Tuscaloosa River, half a mile long, we see at the upper end and near the center of the bluff a preponderance of laminated clays with thin intervening sheets of cross bedded sands, but at the lower end of the bluff the clays disappear or cease, not, however, by dipping below the water level, but abruptly, and they are replaced by thick beds of yellow sand which neither overlie nor underlie the clays, but are substituted for them on the same horizon. Again, at Merriwether's Landing, farther up the river, where the bluff is perhaps half a mile long, at the landing (upper

end of the bluff) we find the bluff made up of laminated clays with sand partings, the sand partings becoming thicker and thicker as we descend, and assuming within 10 feet of the water the character of cross bedded sands with thin clay sheets following some of the lines of false bedding. One hundred yards or less below the landing the whole bluff appears to be cross bedded sands with clay seams, including, about twenty feet above the water, a 10 foot bed of sand. These change again, not because of the dipping of the strata below the river level, but because of the replacement at the same horizon of one set of beds by another.

The great mass of the Eutaw formation seems to have been deposited in shallow water by ever varying currents.

The absence of all fossils except an occasional lignitized tree trunk and the lack of any persistent or easily identified beds of any kind make it impossible for us here to sum up the thickness as we have done in the Tertiary group, and we are therefore compelled to rely either upon width of outcrop across the country of the beds of this formation or upon the borings for artesian wells. The thickness of the beds of this formation, estimated from their outcrop along the banks of the Tuscaloosa River from Finch's Ferry to Big Log Shoals, on an assumed uniform dip of 40 feet to the mile, is about 200 feet; but this estimate is probably too small. Between Big Log Shoals and White's Bluff no Cretaceous rocks are exposed on the river, but they may be seen upon the neighboring hills, and recent observations of Mr. Langdon and myself indicate that this stretch of the river is almost entirely underlaid by the beds of the Eutaw formation; and if this is so their total thickness can hardly be less than 300 feet. This estimate is confirmed by the width of the outcrop of the Eutaw beds upon the hills on both sides of the Tuscaloosa River. On the eastern side, in Hale County, they are found from three miles south of Havana down to Greensborough, and on the western side, in Green County, from just south of Knoxville down to Eutaw, or in each case about 10 miles in a direct line across the strike. This with a uniform dip of 30 feet to the mile would correspond to a thickness of 300 feet, and with a dip of 40 feet per mile to 400 feet; 300 feet may therefore be given as the minimum thickness of these beds along the Tuscaloosa. A boring now in progress at Eutaw reached the purple clays of the Tuscaloosa formation at a depth of 400 feet; which indicates a thickness for the formation nearly the same as that estimated from the width of outcrop and dip. The corresponding portion of the course of the Alabama River—i. e., between Selma and Montgomery—is such that the lowermost members of this formation are not there exposed.

SECTIONS OF THE EUTAW FORMATION.

The following sections illustrate fairly well the lithologic and other peculiarities of the Eutaw formation, including the transitional beds, which may hereafter, upon paleontologic grounds, be classed with the Rotten Limestone.

(*a*) *Section of the bluff at Erie, Tuscaloosa River.* (*Plate XX, Fig.* 1, *p.* 175.)

1. Rotten Limestone of usual character ....30 feet.
2. Indurated ledge of calcareous sand, containing grains of glauconite, strongly phosphatic and in part filled with oyster shells ....5 to 8 feet.
3. Yellowish sands containing shells in the upper part, and thus forming a continuation of the preceding ....8 feet.
4. Projecting hard ledge filled with small bivalve shells, chiefly oysters, 8 to 12 inches.
5. Yellowish sands, with some glauconite, becoming more and more glauconitic as we descend ....5 to 6 feet.
   The lower part of this stratum, say one or two feet, is indurated, shells become more abundant, and there is thus a gradual transition into the next underlying bed. In these sands, which are hollowed out from beneath the preceding ledge, there are embedded some curious stalagmitic formations, of indurated calcareous sand, which stand up like small pillars. These are strongly phosphatic, and have much the appearance and composition of the ledge No. 4.
6. Indurated ledge of sand, greensand, and shells, mostly oysters, like that at Choctaw Bluff ....1 foot.
7. Greensand, cross bedded ....3 to 4 feet.
8. Laminated, blue clay, in several distinct layers, which project from the vertical faces formed by the greensand above and below it ....2 feet.
9. Greensand like No. 7, but with more glauconite to water's edge; contains much phosphoric acid ....1 foot.

Just above Erie there is a great southwestward bend in the river, by reason of which only the Rotten Limestone appears in the river banks, the greensands being all below the water level. This condition of things continues up to McAlpine's Ferry, where we have the following:

(*b*) *Section near McAlpine's Ferry, Tuscaloosa River.* (*Plate XX, Fig.* 2, *p.* 175.)

1. Rotten Limestone of variable thickness, with a covering of drift above it.
2. Calcareous sands, indurated and glauconitic, partly filled with shells, mostly oysters ....6 to 8 feet.
3. Sands ....8 to 10 feet.
4. Greensand to water's edge ....6 feet or more.

From Eastport, just above McAlpine's Ferry, up to Melton's Bluff the course of the river is nearly along the strike of the strata, and we have practically the same beds as those above described at Erie along this stretch of the river. The undulations which are usually observed along the outcropping edges of our Tertiary and Cretaceous strata may be seen here also.

(*c*) *Section at Melton's Bluff and Eastport, Tuscaloosa River.*

1. Cross bedded sands, grading off below into greensand ....10 feet.
2. Greensand, forming a bench or ledge 6 to 8 feet broad and 3 feet thick down to the water's edge.

Between Melton's Bluff and Choctaw Bluff another great southwestward bend in the river causes the greensands to disappear below the water level, to reappear near the last named bluff, where we get the following very interesting section, which, however, embraces practically the same beds with the Erie bluff, the two places being situated from each other in the direction of the strike of the strata.

(*d*) *Section at Choctaw Bluff, Greene County, Tuscaloosa River.* (*Plate XX, Fig. 3, p. 175.*)

1. Rotten Limestone of the usual appearance, with a cover of drift or second bottom deposits. The rock contains some fossils, Inocerami, and bones of reptiles, 20 feet or more.
2. Indurated, calcareous sands, with some glauconite, filled with shells, mostly *Exogyra*, forming a projecting ledge, which is a very prominent and persistent mark along the face of the bluff[1] .... 6 to 7 feet.
3. Yellowish, cross bedded sands, shading off above into the fossiliferous ledge. These sands become more and more glauconitic and devoid of fossils below...... 15 feet.
4. Indurated ledge of glauconitic sands and small oysters, slightly effervescent, phosphatic .... 1 foot.
5. Highly glauconitic sands, strongly phosphatic. These sands show above the water at the upper end of the bluff 6 to 8 feet, but sink below the water at the lower end, making a dip of about 20 feet to the mile along this stretch of the river.

This section shows well the point of contact of the Rotten Limestone with the glauconitic beds below it. The beds immediately under the Rotten Limestone are coarse, calcareous sands, somewhat indurated and filled with the shells of Exogyra, No. 2 above. Both the Rotten Limestone and the ledge are filled with nodular masses of iron pyrites. One mile below this, at Stevens's Bluff, the sands are all below the water, and only the Rotten Limestone above it; the same is true of the banks at Hamlet's Shoals. These beds, as above intimated, have acquired a considerable interest from the fact that most of them are strongly impregnated with phosphoric acid. This seems to be particularly the case with the glauconitic sands, especially when they are indurated; and in many cases the induration seems to be due to the formation of phosphates. Wherever the beds immediately underlying the Rotten Limestone have been examined, from the Mississippi line eastward to Wetumpka, and even farther toward the Georgia line, they have been distinguished by containing very notable quantities of phosphate of lime, either impregnating the greensands in a general way or concentrated into irregularly shaped nodules of nearly pure phosphate of lime. These, should they ever be found in sufficient quantity, will be of great value as an article of export. The phosphatic greensands, without the least doubt, can be very profitably used as fertilizers where they are convenient to transportation. This subject, however, will be more specially treated in the report of the Geological Survey of Alabama.

At Finch's Ferry, near Eutaw, on the Tuscaloosa River, there is a bluff which varies from 50 to 75 feet in height, in which strata underlying the phosphatic sands of Choctaw Bluff are seen. The upper 25 to 40 feet of this bluff (according to locality) consist of yellowish, cross bedded sands, in which a few indistinct fossils have been found, and below this some 25 feet of alternating blue clays and cross bedded sands;

[1] This bed has been called "Concrete Sand" by Prof. A. Winchell, and the next below it, "Loose Sand" (Proceedings Am. Assoc. Adv. Sci., Vol. X, Part II, p. 92, 1856). He, however, limits the former name to the first 2 or 3 feet below the Rotten Limestone.

then, forming base of the bluff, about 20 feet of laminated, blue clays, with partings of sand. No fossils have yet been observed in these lower beds.

(*e*) *Section at Finch's Ferry, Tuscaloosa River.* (*Plate XX, Fig.* 4, *p.* 175.)

1. Yellowish, cross bedded sands, with indurated bands at intervals. This sand contains a few casts of shells, mostly oysters, and pieces of silicified wood..25 to 40 feet.
2. Laminated, blue clays, with partings of sand..........................10 feet.
3. Alternations of cross bedded sands and blue, laminated clays...............5 feet.
4. Bluish, glauconitic sands..10 feet.
5. Laminated, blue clays, the laminæ separated by thin sand partings.......20 feet.

The exact position of this section with reference to that at Choctaw Bluff is not certainly made out, but it is quite possible that some of the lowermost of the Choctaw Bluff beds may appear in the highest parts of the bluff at Finch's Ferry. At all events the two sections are very nearly conterminous.

On the Alabama River the same beds are seen at the Batte Smith Bluff, Cunningham's Bluff, and the House Bluff.

At the last-named locality we have perhaps the best section of the transition beds between the Rotten Limestone and the Eutaw formations to be seen in the State.

This bluff, gapped by ravines, forms the northern bank of the river for a mile or more at the top of one of those long bends made by the Alabama in this part of the State. Near the lower or western end of the bluff, where these gaps are close together, the sharp crested, interjacent ridges come out to the face of the bluff in cross section like the gable ends of a house, whence the name of the bluff.

The uppermost (i. e., most eastern) of these bluffs has about thirty feet of Rotten Limestone on top, and the washings from this have whitened all the underlying red and yellow sands, so that if not closely examined the white bluff would easily be mistaken for limestone throughout. The next bluff below separated from this by a narrow ravine only, and of nearly the same height, consists of yellow, cross bedded sands to the very top. The absence of the Rotten Limestone on top of this second bluff and its presence on top of the next succeeding or third bluff are due to undulations in the strata. The contrast between the first two bluffs is very striking. The uppermost bluff is probably the highest of the set and is about one hundred and fifty feet high, and the strata exposed in it are the following:

(*f*) *Section of the House Bluff.* (*Plate XX, Fig.* 5, *p.* 175.)

1. Rotten Limestone..20 to 30 feet.
2. Greensand, with phosphatic nodules....................................4 feet.
3. Conglomerate of shells embedded in loose sand...........................1 foot.
4. Light colored sands, with irregular deposits of shells and a six inch layer of shells at bottom..5 feet.
5. Sands 8 feet, with a layer of shells at bottom, 1 foot, in all...............9 feet.[1]

[1] Nos. 2 to 5, inclusive, constitute the "Concrete Sand" of Dr. Winchell.

6. Alternating beds of horizontally laminated and cross bedded sands, yellow (glauconitic); the separate beds from 1 to 2 feet thick. These beds are marked with numerous streaks deeply colored with iron .... 40 to 50 feet.
7. Laminated clays (soapstone), devoid of fossils .... 10 feet.
8. Blue, micaceous sands, no fossils .... 15 feet.
9. Light colored sands, with large, bowlder-like concretions of concentric layers .... 20 feet.
10. Alternations of the laminated clays and blue sands above described down to the water level.

The great irregularity in the stratification of the sands of this formation is well exhibited in the House Bluff, where hardly any two sections will show the same sequence of beds. The following section of this bluff was taken by me in the summer of 1886, and shows the stratification of the first quarter of a mile of the bluff rather than that of a single locality:

(f) Section of the upper part of House Bluff.

1. Rotten Limestone, including near the base a bed of phosphatic greensand four and a half feet in thickness .... 30 feet.
2. Ledge of oyster shells embedded in sands, forming a hard ledge .... 8 inches.
3. Whitish sands .... 8 to 10 feet.
4. Ledge of shells like No. 2 .... 5 to 11 inches.
5. Yellowish, cross bedded sands, indurating into rounded, bowlder-like masses of concentric structure. On the weathering and caving of the bluff, these bowlders break off and roll down to the water's edge and cover all the slope below them. The two hard ledges of shell conglomerate also break off in a similar way, and their fragments also cover the slope below .... 50 to 60 feet.
6. Yellowish, cross bedded sands like the preceding, except that they are traversed by clay bands and partings of very irregular thickness and extent .... 10 feet.
7. Compact sands, making a smooth, perpendicular face .... 15 feet.
8. Cross bedded sands, the lower part containing gray clay partings, and in the lowermost 5 feet merging into bluish gray, laminated clays .... 15 feet.
9. Blue sands to the water's edge .... 5 feet.

The resemblance between this section and those of Choctaw Bluff and Finch's Ferry, Tuscaloosa River, is sufficiently strong to justify us in correlating them in a general way, though we cannot, of course, expect to find absolute identity in the individual beds.

The two ledges of shell conglomerate appear in the hills in many places westward of this bluff. Between the two Mulberry creeks, one and a half miles west of Statesville, they are nearly at the general level of the high table lands; and everywhere about seven or eight feet above the upper of these ledges, appears the bed of phosphatic greensand, so well known in the vicinity of Hamburg, in Perry County. These beds rise toward the north and appear in several places in Autauga County, high up on the hills. In the vicinity of the old Slaton place and the old Jim Brown place, the shell conglomerate and the greensands are exposed over a large territory.

bluffs of the Alabama River, from House Bluff up to Mont- ow more or less of the House Bluff beds, according to the f the river. At Washington Ferry the banks are made of

the laminated gray clays with interbedded sands, which are seen near the base of House Bluff. About two hundred yards above the Washington Ferry there is a high red bluff showing the following:

(f^2) Section of bluff near Washington Ferry, Autauga County.

1. Drift and red loam ....10 to 15 feet
2. Cross bedded, yellow sands, stained deep red by the washings from No. 1..50 feet.
3. Laminated clays and sands ....50 feet.

No. 2 above corresponds with No. 5 of my House Bluff section, while No. 3 corresponds to the rest of the House Bluff.

The river bluff, just below the steamboat landing at Montgomery, shows the following:

(f^3) Section at Montgomery.

1. Drift (very closely resembling what we have called second bottom deposits), 15 to 20 feet.
2. Laminated, gray sands, with gray clay partings..........................3 feet.
3. Gray clayey sands, with white and gray clay partings.....................4 feet.
4. Rather compact, yellow sands with small, lens-shaped, spherical, and other irregularly shaped masses of pure, gray clay scattered through the mass of sands. These form the greater part of the perpendicular bluff to the river below the drift deposits, and extend to the water's edge ....25 to 30 feet.

Where the Rotten Limestone is seen at the summit of the bluff, as at Choctaw Bluff and at House Bluff, the geological horizon of the underlying beds of the section is at once determined. The uncertainty is felt only in regard to the exact relative position of the Finch's Ferry beds and those where the Rotten Limestone is absent.

Between Finch's Ferry and Big Log Shoals, a distance of four and a quarter miles or a little more, across the strike, which corresponds to a thickness of about one hundred and fifty feet of strata, the banks of the river are composed of laminated, bluish clays and cross bedded, glauconitic sands, in many alternations. Interbedded with these, at two or three points, are thin beds of pebbles, from eight to twelve inches thick, and thin layers of lignitic matter, consisting of lignitized stems, twigs, and other fragments, embedded in bluish sands. In addition to these, lignitized trunks of trees are not infrequently seen at many of the exposures. Occasionally, also, a silicified trunk is to be found lying upon the bluff, but whether derived from the Cretaceous or from the overlying drift deposits is still a matter of doubt.

It has as yet been impossible to ascertain the actual sequence of these different beds for the whole distance mentioned above, but the following detailed sections will probably cover nearly their entire thickness.

Immediately below the laminated clays which form the base of the exposure at Finch's Ferry, come alternations of similar laminated clays, with cross bedded sands many feet in thickness, which are to be seen at Semple's Bluff, just above the railroad bridge, and at Collins's wood yard, where about ten feet of thickness are to be seen.

Childs's Ferry.—At Childs's Ferry similar strata are exposed, the bluff being some thirty feet high. The lower part of this exposure consists, without doubt, of the same beds as those at the top of the bluff at Merriwether's Landing, given below:

(*g*) *Section at Merriwether's Landing, Tuscaloosa River.*

1. Laminated clays and sands; the sands are bluish green in color when freshly exposed, but become yellowish on weathering........................10 to 15 feet.
2. Sands...7 to 8 feet.
3. Laminated sands and clays again to the water's edge............20 feet or more.

Much of the blue clay in the lower part of this bluff breaks up on drying into small chips, which are covered with white efflorescence derived from the oxidation of iron pyrites, nodules of which are of common occurrence in the clay. Along the bluff are to be seen many trunks of trees, either lignitized or silicified.

The lowermost five or ten feet of the beds exposed at Merriwether's are seen again at the top of the bluff at Long Bend, where the following section is exposed:

(*h*) *Section at the head of Long Bend, Tuscaloosa River.*

1. Cross bedded sands forming top of bluff...........................5 to 10 feet.
2. Laminated, blue clays..2 to 3 feet.
3. Bed of quartz pebbles..2 to 3 feet.
4. Laminated, blue clays again, containing galls or concretions of pure, light colored clay..4 to 5 feet.
5. Coarse grained, yellowish sands, strongly cross bedded, running down to the water level...5 feet or more.

Hickman's.—At Hickman's, below Big Log Shoals, the bluff is made up of laminated clays alternating with cross bedded sands in the most irregular manner. The thickness of these beds was not estimated, but their relative position is as follows:

(*i*) *Section at Hickman's, Tuscaloosa River.*

1. Cross bedded sands of yellowish color on exposed surfaces, probably 10 feet or more in thickness.
2. Laminated, blue clays, more or less sandy and containing lignitized tree trunks, which are, in general, pyritous. The laminated, blue strata in the upper part of this division are much more clayey than those in the lower part, and mark the bluff with parallel and approximately horizontal stripings, probably 5 to 10 feet.
3. Cross bedded sands again down to the water's edge.

At the head of Big Log Shoals we have another section of ten or twelve feet, as follows:

(*j*) *Section at the head of Big Log Shoals, Tuscaloosa River.*

1. Compact, blue, micaceous sands......................................3 to 4 feet.
2. Laminated sands..3 to 4 feet.
3. Lignitic stratum, consisting of lignitized twigs, stems, and other fragments, embedded in bluish sands..1 foot.
4. Alternating layers of blue clay and bluish, micaceous sands, the latter including a bed of pebbles 8 to 10 inches in thickness...............................4 to 5 feet.

This section represents the lowermost of the blue clays and cross bedded sands, which we have considered as belonging to the Eutaw formation of the Cretaceous group, leaving undetermined some seventy-five feet from this to White's Bluff. At the latter begins what we shall now call the Tuscaloosa formation.

III. OTHER MESOZOIC STRATA, PROBABLY CRETACEOUS.

§ 1. THE TUSCALOOSA FORMATION.

Underlying the strata last described, and forming all the country between White's Bluff and the city of Tuscaloosa, are beds whose age has not been certainly determined.

The most conspicuous rocks are purple and mottled clays interstratified with white, yellowish white, pink, and light purple, micaceous sands, and near the base of the formation dark gray, nearly black, thinly laminated clays, with sand. partings. Typical sections of the mottled clays and white sands may be seen at Steele's Bluff and at White's Bluff on the Tuscaloosa River; and a beautiful section of the pink, micaceous sands is exposed in two large gullies below Havana, in Hale County, near the residence of Hon. A. M. Avery. The dark gray, laminated clays are well seen near and in the city of Tuscaloosa.

All the beds of this formation, being of loose clays and still less coherent sands, have suffered a great amount of denudation, and in consequence they form the banks of the river at only a few points.

(1) SUMMARY OF PREVIOUS OBSERVATIONS AND OPINIONS.

The peculiar formation above described appears to have been observed a third of a century ago by Prof. L. Harper, then State Geologist of Mississippi, and by Prof. Alexander Winchell.

In 1856 Professor Harper described three specimens of *Ceratites*, which he called *C. Americanus*,[1] found by him in 1853 in the bed of the Tuscaloosa (or Warrior) River near Erie, and pronounced by the elder Agassiz "closely allied to *Ceratites Syriacus* of L. v. Buch," from the Cretaceous rocks of the Caucasus. Professor Harper considered it "somewhat doubtful" whether this was a Cretaceous fossil, and suggested that it was washed out from the formation underlying the known Cretaceous beds of that section of Alabama. He adds: "What formation this is seems difficult to decide, it being devoid of fossils. It must, of course, be one of the older formations intermediate between the coal [Carboniferous] and the lime [Cretaceous], and I should not at all be astonished if a careful examination should give the result of its classification among the poikilitic rocks, to which this variegated clay bears great resemblance."[2] Subsequently, in his Report on the Geology of

[1] Proc. Acad. Nat. Sci. Phila., Vol. VIII, pp. 126–128.

[2] Ibid., p. 28.

Mississippi,[1] he speaks of the occurrence of a clay of gree
with red streaks, penetrated by a boring for an artesian
bus, Miss., and he looks upon the occurrence of this clay
that "there exists between the Cretaceous and the Carbo
tions an intermediate one, perhaps the Permian;" and in th
tion he again mentions the occurrence of great beds of v
below the greensand of the Cretaceous formation above t
taw, in Alabama, and repeats his suggestion that the t
of Ceratites were "most probably washed out of a form
ing the Cretaceous formation." With respect to the ag
cretaceous formation he adds: "The *Ceratites* being espe
the Triassic formation, it is possible that this formation
Cretaceous."[2]

In 1856, also, Professor Winchell mentioned the beds of
which underlie the sands of Finch's Ferry, remarked
gated and mottled colors of the clays and also of the red
added that in Greene County many of the artesian wells w
these beds furnish a constant supply of salt water (show
rence of local deposits of salt), while the deeper borings
abundance of quartzose pebbles; all of which he consid
with the supposition that these deposits are of Triassic a
position is still further strengthened by the occurrence
vegetables appearing like the stems and leaves of dicotyl
* * * some specimens of which appeared to me indist
stems of *Equisetites*." Professor Winchell also remarks
scarcity of any organic remains in all these beds, ex
very suburbs of the city of Tuscaloosa, which, he says, "
termination of their age extremely doubtful;"[4] and he
fully convinced of the Triassic age of the beds, since
principal strata,[5] he includes them in the Lower Cretace

From these extracts it seems certain that both Harpe
were aware of the existence of this formation as early as
1853. No unmistakable reference to these strata ha
in Professor Tuomey's writings, though he must h
the observations of the two gentlemen above named.
membered, however, that at the time of his death Pro
had a large number of unpublished notes on the geolog
many of which have been lost. It is true that in 18
scribed certain "superficial beds of red loam," &c.,[6] an
as 1846 Lyell mentioned "great beds of gravel and sand"

[1] Prel. Rep. Geol. and Agric. Miss., p. 279, 1857.
[2] Ibid., p. 280.
[3] Proc. Am. Assoc. Adv. Sci., Vol. X, Part II, p. 92, 18
[4] Ibid., p. 93.
[5] Ibid., p. 84.
[6] First Bien. Rep. Geo. Ala., p. 164, 1850.

of Tuscaloosa;[1] but these great beds of gravel, sand, and loam which constitute so large a proportion of the surface material about Tuscaloosa are undoubtedly, as Professor Tuomey has said, of comparatively recent age, though possibly derived primarily from a Mesozoic formation. Certainly neither Lyell's nor Tuomey's description applies to the predominant beds of the Tuscaloosa formation, and it appears equally certain that, when their descriptions were written, neither of these authors had in view the laminated and mottled clays of the formation, which appear only here and there in comparatively insignificant exposures in a few of the gullies back of the city, the majority of these gullies exposing only post-Tertiary gravels and sands.

The age of the various Mesozoic deposits of Alabama was discussed at great length nearly thirty years ago by Hall, Meek, Conrad, Hayden, and others.

In 1855 Hall and Meek, referring to Tuomey's publications, classed the various Mesozoic strata of Alabama as Cretaceous.[2] Two years later Meek and Hayden, making use of the information published by Tuomey, Harper, and A. Winchell, together with additional matter privately communicated by the last named gentleman,[3] correlated the lower portion of the Alabama Mesozoic[4] with the lowest Cretaceous formation of New Jersey and Nebraska and the lower strata of Pyramid Mountain, New Mexico (regarded by Marcou as Jurassic and Triassic).[5] Among their conclusions are these:

> 7th. There is at the base of the Cretaceous system, at distantly separated localities in Nebraska, Kansas, Arkansas, Texas, New Mexico, Alabama, and New Jersey, if not indeed everywhere in North America where that system is well developed (at any rate east of the Rocky Mountains), a series of various colored clays and sandstones, and beds of sand, often of great thickness, in which organic remains, excepting leaves of apparently dicotyledonous plants, fossil wood, and obscure casts of shells, are very rarely found, but which everywhere preserves a uniformity of lithological and other characters, pointing unmistakably to a similarity of physical conditions during their deposition over immense areas.
>
> 8th. Although the weight of evidence thus far favors the conclusion that this lower series is of the age of the Lower Greensand, or Neocomian of the Old World, we yet want *positive* evidence that portions of it may not be older than any part of the Cretaceous system.[6]

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[1] Quar. Jour. Geol. Soc., Vol. II, p. 280, 1846; Second Visit to North America, Vol. II, p. 79, 1855.

[2] Trans. Am. Acad., Vol. V, p. 380, 1855.

[3] Proc. Acad. Nat. Sci. Phila., Vol. IX, pp. 117–133, 1857.

[4] Described (Proc. Acad. Nat. Sci. Phila., Vol. IX, p. 126, 1857) as "beds of dark blue, soft shale or indurated clay, alternating with strata and seams of white and mottled clays, green and ferruginous sand, and dark, pyritiferous shale. No organic remains, but stems and leaves of apparently dicotyledonous plants and a few obscure casts of other fossils. *Ceratites Americana* of Harper, is, however, supposed to hold a position somewhere in this series."

[5] Pac. R. R. Rep., Vol. III, Résumé and Field Notes, p. 137, 1853–'54.

[6] Proc. Acad. Nat. Sci., Vol. IX, p. 133, 1857.

Later, in the same year, Hall[1] pointed out that Marcou's erroneous reference of the Pyramid Mountain beds to the Jurassic and Triassic was at least partly due to mistaken identification of certain fossils, and followed the former authors in definitively referring the several formations in question to the Cretaceous, of which the lower division is "represented by No. 1 of the Nebraska section, and including the various sandstones and shales or clays at the base of the formation in the Llano Estacado and other portions of New Mexico; and probably equivalent to the lower clay beds of New Jersey [and Alabama],[2] in which the only fossils yet known are of vegetable origin,"[3] while Conrad was of the opinion that the Cretaceous deposits of Alabama form a passage or intermediate stage between the Cretaceous strata of Texas and those of New Jersey.[4] Subsequently Hilgard (who was unquestionably familiar with the suggestions of Harper and Winchell as to the pre-Cretaceous age of the clays and sands resting upon the Carboniferous strata in Alabama and Mississippi) united the beds immediately beneath the Tombigbee sands and the subjacent highly colored clays and sands, applied the name Eutaw group to the formation thus defined, and referred it to the Cretaceous.[5] In the following year Meek and Hayden re-expressed their convictions as to the age of the lowest Mesozoic beds of Alabama, correlated the beds subsequently described by J. S. Newberry[6] and B. F. Shumard[7] with the formation to which they had already referred these deposits, and applied to it the name Dakota group.[8] In 1869 Safford followed Hilgard in uniting the lowest Mesozoic beds of Western Tennessee with the immediately superjacent strata containing Cretaceous fossils; and to the formation thus defined he gave the name Coffee Sand.[9] The latest specific expression on the subject known is that of Meek, who, in 1876, with the entire information available before him up to the initiation of the investigations herein described, maintains his opinion that the beds of dark blue, soft shale or indurated clay &c. of Alabama, the plastic clays of New Jersey, and the yellow and brown sandstones and green shales of New Mexico, to which he added the Eutaw group of Mississippi, are Cretaceous and the equivalent of the Dakota formation of Dakota, Nebraska, and Colorado;[10] but Lesquereux has recently correlated the Dakota

[1] Am. Jour. Sci., 2d ser., Vol. XXIV, pp. 72–86, 1857; also Rep. U. S. and Mex. Bound. Surv., Vol. I, Pt. II, 1857.

[2] Am. Jour. Sci., 2d ser., Vol. XXIV, p. 75, 1857.

[3] Ibid., p. 83.

[4] Rep. U. S. and Mex. Bound. Surv., Vol. I, Pt. II, p. 141, 1857.

[5] Rep. Geol. and Agr. of Miss., p. 61, 1860.

[6] Rep. Expl. Exped. 1859 under Macomb, p. 52, 1876; Am. Jour. Sci., 2d ser., Vol. XXIX, p. 208, 1860.

[7] Trans. Acad. Sci. St. Louis, Vol. I, pp. 582–590, 1856–1860.

[8] Proc. Acad. Nat. Sci. Phila., Vol. XIII, pp. 419–421, 1861.

[9] Geol. of Tenn., p. 411, 1869.

[10] U. S. Geol. Surv. Terr., Vol. IX, pp. 38–42, 1876.

group of Meek and Hayden with the Cenomanian of Europe,[1] thereby increasing the probability that the formations subjacent to the Eutaw or other well defined portions of the Dakota group may belong to the Cretaceous.

Examination of their literature shows, however, that these geologists failed to discriminate the poorly fossiliferous beds denominated Eutaw in Mississippi and Alabama and Coffee Sand in Tennessee from the subjacent and apparently much older formations now in question; and, since their determination of the age of the entire series of strata rests on the evidence of the fossils from the admittedly Cretaceous Eutaw group, their opinion as to the age of the subjacent formations is of little value.

Although the poverty of the formation in organic remains precludes the possibility of determining its precise position in the geologic series, its relation to other Mesozoic formations of the eastern United States is suggested by its attitude, its lithologic character, and its stratigraphic position.

On comparing it with the Red Sandstone of New Jersey and Connecticut (generally regarded as Triassic, though W. M. Fontaine has recently pronounced certain bodies of it Rhætic < Lower Liassic[2]) marked differences are found to exist. Thus the deposits of the Tuscaloosa formation are seldom lithified, while those of the Red Sandstone are, in general, firm sandstones, conglomerates, and shales; the strata of the Tuscaloosa formation are little disturbed (having only a gentle inclination of thirty or forty feet per mile to the seaward), while the Red Sandstone is everywhere highly tilted, faulted, slickensided, and sometimes contorted; the former formation has never been affected by intrusives, while the latter is intersected by trap dikes and interbedded with trap sheets; vegetal matter in the formation exposed along the Tuscaloosa River is comparatively little altered, and often retains its woody texture, although it is usually converted into lignite, while the carbonaceous matter of the Red Sandstone on Deep and Dan Rivers and elsewhere has been converted into true coal. Both formations are alike unconformable to the subjacent and Paleozoic and Azoic formations; but while the former is sensibly conformable to known Cretaceous formations the latter is apparently separated from the adjacent (but nowhere contiguous) later Mesozoic deposits by one of the greatest unconformities of the American rock series; and finally, while only slight and uniform elevation appears to have occurred in the eastern part of the continent since the formation of the Alabama deposit, great changes in continental configuration have unquestionably taken place since the formation of the highly tilted Red Sandstone of New Jersey and the Connecticut Valley. Accordingly these formations could not

[1] Rep. U. S. Geol. Surv. Terr., Vol. VIII, pp. 92, 105, 1883.
[2] Mon. U. S. Geol. Surv., Vol. VI, pp. 96, 128, 1883.

legitimately be correlated without the strongest possible paleontologic evidence; and such evidence has not been found.

But on comparing the formation with the younger Mesozoic deposits of Eastern Virginia, Central Maryland, Northern Delaware, Southeastern Pennsylvania, and perhaps Central New Jersey and Southern New York—the Potomac formation of McGee—there is found to be so striking similarity in attitude, in composition, in degree of lithification, and in stratigraphic position that the description of the one in general terms will equally apply to the other; and this similarity will warrant provisional correlation of the formations.

The age of the Potomac formation has not, however, been satisfactorily determined, as the following history of opinion concerning it indicates:

It appears to have been first discriminated by R. C. Taylor[1] who, in 1835, spoke of it in one of its exposures as "The Secondary Horizontal Strata of Fredericksburg," and described half a dozen species of fossil plants from it, and, on the evidence of the plants, referred it to the "Oölitic group of Europe." Its probable equivalent was again separated from the fossiliferous Cretaceous deposits in New Jersey in 1840 by H. D. Rogers, who denominated it the "Potter's Clay formation," referred it to the "Upper Secondary series,"[2] (in contradistinction to the "Middle Secondary series," to which the Red Sandstone was relegated), and showed that it passes gradually upward into the greensand division of the Cretaceous. In the following year it was specifically designated the "Red Clay formation" in Delaware, and referred to the "Upper Secondary formation," on the ground of its resemblance to the "Secondary" formation of Europe;[3] and in the same year it was described in Virginia by W. B. Rogers, who denominated the formation the "Upper Secondary Sandstones and Conglomerates,"[4] in contradistinction to the "Middle Secondary Sandstone" &c. (comprised in the Rhætic of Fontaine). In 1842, he referred it to the Oölitic[5] and again in the same year (as a subsequent publication indicates) "to the upper part of the Jurassic series, corresponding probably to the Purbeck beds of British geologists."[6] The bases for these references appear to have been (1) the evidence of undescribed plant and animal remains, (2) the lithologic character of the deposits, and (3) the stratigraphic relations of the formation. In 1845, after examining this and associated formations in company with Conrad, Sir Charles Lyell[7] "arrived at the conclusion that the whole of the New Jersey series [of

[1] Trans Geol Soc. Pa., Vol I, pp 320–325, 1835.
[2] Geol. of N. J., Final Rep., pp 177–179, 1840.
[3] Memoir Geol. Surv. Del., 1837–'38, pp. 14–16, 1841.
[4] Rep. Prog. Geol Surv. Virg., p. 29, 1840
[5] Reprint, Geol. of the Virginias, p. 542.
[6] Proc Bos. Soc. Nat. His., Vol. XVIII, p. 104, 1875.
[7] Trav. in N. A., Vol. I, p. 63, 1845.

Cretaceous deposits] agrees in its chronological relations with the European White Chalk, or, to speak more precisely, with the formations ranging from the Gault to the Maestricht beds inclusive;" but his language in another publication suggests that his expression is designed to apply only to the fossiliferous formations overlying the plastic clays constituting the upper division of the Potomac formation.[1] Certainly, his conclusion rested in large part on his own observations of conformity and collections of shells from the fossiliferous formations. In 1867, as already mentioned, Meek and Hayden, after visiting the exposures and examining the collections of the State geologic survey and discussing the paleontologic, lithologic, and stratigraphic evidence then available, correlated the plastic clays forming the base of the newer Mesozoic of New Jersey—the "Potter's Clay" formation of H. D. Rogers—with the European Neocomian.[2] In 1860, Tyson recognized what appears to be the same formation in Maryland, denominated it "Formation No. 21,"[3] and, on the questionable evidence of a few imperfectly silicified casts of undetermined fossils, a new genus of Cycas, silicified and lignitized coniferous wood, a fragment of a rib of a whale, and "part of the teeth and bones of an herbiferous Saurian," referred it (including the "Iron Ore Clays") to the Cretaceous; but two years later, on the evidence of the cycad alone, concluded (with the expressed concurrence of L. Agassiz) that it ought to be placed "at least as low as the Oölitic period."[4] On assuming control of the geologic survey of New Jersey, Cook recognized and repeatedly described the formation constituting the base of the newer Mesozoic series. In 1865 he denominated it the "Fire and Potter's Clays" and definitively referred it to the Cretaceous,[5] though without explicit statement of the reasons for the reference. In the same year Leidy[6] adopted the taxonomy of Meek and Hayden, and described and referred to the Cretaceous a reptilian tooth (*Astrodon Johnstonii*) from the "Iron Ore Clays" of Maryland. In 1868, Cook substituted the name "Plastic Clays"[7] for the formation as developed in New Jersey, and correlated it with the Lower Greensand of Europe on paleontologic and stratigraphic grounds. During the same year, however, Conrad[8] referred the formation to the Triassic, on the evidence of two casts of lamellibranchs (called "Cretaceous species" in the title), and a few plant remains referred to the genus Cyclopteris, which he found within it; while Cope, who found within it in Western New Jersey "leaves of dicotyledonous trees, ctenoid fish scales,

[1] Quar. Jour. Geol. Soc., Vol. I, p. 60, 1845.
[2] Proc. Acad. Nat. Sci. Phila., Vol. IX, pp. 127–133, 1857.
[3] First Rep. Agr. Chem. Maryland, pp. 41–43, 1860.
[4] Sec. Rep. Agr. Chem. Maryland, p. 54, 1862.
[5] Ann. Rep. Geol. Surv. N. J., p. 24, 1864.
[6] Smithsonian Cont., Vol. XIV, Cret. Rep. U. S., pp. 2–4, 1865.
[7] Geol. of N. J., pp. 36, 241, 246–248, 1868.
[8] Am. Jour. Conc., Vol. IV, p. 279, 1868.

and numerous Unionidæ in a tolerably good state of preservation," correlated it with Meek and Hayden's "Earlier Cretaceous No. 1" (Dakota), although the six species of Unios and Anodontas contained within it have "some analogy with those of the Wealden, procured by Dr. Mantell in England."[1] In 1875 W. B. Rogers,[2] referring to Tyson's discovery of stumps of cycads in the formation, relegated it to the horizon of the Upper Jurassic rocks, and suggested that "we may find here a passage group analogous to the Wealden of British geology." In the next year, after an exhaustive review of its paleontologic and stratigraphic relations, Meek[3] referred the formation unquestioningly to the Cretaceous, and suggested that it represents a "part, if not the whole, of the Upper Greensand." In 1878 Cook retained the name "Plastic Clay" for the formation as developed in New Jersey, and, on the authority of Lesquereux and Gabb, who examined, respectively, the plant and animal remains found within it, again correlated it with the Lower Greensand of Europe.[4] Lesquereux remarks that the plant remains of the formation have, "so far as they are determinable, the characters of the flora of the Dakota group, or of the Lower Cretaceous of Nebraska and Kansas. This is Lower Cretaceous for this country, equivalent to a lower member of the Upper Cretaceous of Europe."[5] During the next year Fontaine described the formation as exhibited in the Fredericksburg and Petersburg belts, and, on the evidence of a moderately abundant flora, correlated the upper division of the strata of the former belt with the Wealden[6] and those of the lower part with the Upper Oölite,[7] and referred the whole of the Petersburg belt to the Wealden.[8] In 1880 (?) Dana[9] adopted the taxonomy of Meek and Hayden, and referred the Plastic Clay of Cook and the correlative deposits in Delaware, Maryland, and Virginia to the Cretaceous, to which he also ascribes the Alabama beds supposed to yield Harper's doubtful genus *Ceratites*.[10] In 1881 this formation was recognized in Pennsylvania by C. E. Hall[11] (though its existence there was long ago denied by H. D. Rogers),[12] who denominated it "Wealden Clay" and classed it as "a remnant of the lowest clay beds of the New Jersey Cretaceous (Wealden ?)." In the same year Britton[13] denominated

[1] Proc. Acad. Nat. Sci. Phila., Vol. XX, p. 157, 1868.
[2] Proc. Boston Soc. Nat. His., Vol. XVIII, p. 105, 1875.
[3] Rep. U. S. Geol. Surv. Terr., Vol. IX, p. xliv, 1876.
[4] Rep. Clay Deposits of N. J., pp. 25-30, 1878.
[5] Ibid., pp. 27, 28.
[6] Am. Jour. Sci., 3d ser., Vol. XVII, p. 156.
[7] Ibid., p. 157.
[8] Ibid., p. 233.
[9] Man. of Geol., Dana, 3d ed., pp. 454-458.
[10] Ibid., p. 468.
[11] Sec. Geol. Surv. Pa., Rep. Prog., C⁶, p. 19.
[12] Geol. Pa., Vol. I, p. 59, 1858. "Tertiary and Cretaceous strata border the State upon the SE. in New Jersey, but they do not cross the Delaware River into Pennsylvania."
[13] Ann. N. Y. Acad. Sci., Vol. II, p. 170, 1882.

the formation as represented on Staten Island the Cretaceous formation and remarked that it is "a direct continuation of the 'Plastic Clay' division of the Cretaceous, so named by the New Jersey geologists, and lie[s] at the base of the formation in Eastern North America." Newberry[1] also, during the same year, expressed the conviction that these strata are Cretaceous. In 1883 Fontaine[2] discriminated the older Mesozoic and the younger Mesozoic of Virginia, and remarked that "the younger Mesozoic strata have very little in common with" the older, but expressed no more definite opinion as to their age. In the same year Uhler[3] described the formation as developed in Maryland in a popular address, discussed its flora and fauna, denominated it the Wealden, and referred it to the upper part of the Jurassic. A year later Chester[4] applied the New Jersey name of Plastic Clay to the formation in Delaware and referred it to the "Lower Cretaceous (Wealden ?)," but upon what basis is not evident. In the same year appeared W. B. Rogers's posthumous geologic map of Virginia and West Virginia,[5] in which the formation is classed as "Upper Jurassic passing upward into base of Cretaceous." In the same year also McGee,[6] after assembling and adjudicating the entire available evidence as to the age of the formation, provisionally mapped it as Cretaceous.[7] One of the latest published expressions, and perhaps the most authoritative, is that of R. P. Whitfield, who describes five species of lamellibranchiate shells from this formation in New Jersey. Whitfield considers that "Mr. Conrad may have been mistaken" in regard to the casts of *Astarte* from the ash colored clays of this formation, referred by him to the Triassic, and expressed the "feeling" that the formation more probably represents the Jurassic than the Cretaceous.[8] In the same volume Cook applies the eminently suitable name Raritan Clays[9] to the formation as developed in New Jersey, and, on stratigraphic grounds, adheres to his opinion that the formation is a part of the Cretaceous. Still more recently Fontaine[10] has re-examined the various exposures of the formation in Virginia and made extensive collections of plant remains from them. He finds that while the general facies of the flora is Neocomian there is a notable commingling of Jurassic and even earlier forms. Accordingly the precise equivalence of the formation with any of the European or western American divisions cannot be established.

[1] Trans. N. Y. Acad. Sci., Vol. I, p. 57, 1881–'82.
[2] Mon. U. S. Geol. Surv., Vol. VI, p. 2, 1883.
[3] Johns Hopkins Univ. Cir., Vol. II, p. 53, 1883.
[4] Proc. Acad. Nat. Sci. Phila., pp. 250–2, 1884.
[5] Reprint Geol. of the Virgs., map, 1883–'84.
[6] Fifth Ann. Rep. U. S. Geol. Surv., Pl. II, 1883–'84.
[7] Fifth Ann. Rep. U. S. Geol. Survey, Pl. II, 1885.
[8] Mon. U. S. Geol. Surv., Vol. IX, pp. 22, 23, 1885.
[9] Ibid., p. x.
[10] Sixth Ann. Rep. U. S. Geol. Surv., pp. 85 and 86, 1884–'85.

2. OBSERVATIONS FROM 1843 TO 1883 OF OCCURRENCES ON THE TUSCALOOSA.

The recent work upon the basal Mesozoics in Alabama may be summarized as follows: In the spring of 1883 Mr. L. C. Johnson, while engaged in the work of the U. S. Geological Survey, observed the purple and mottled clays, briefly described above, in Dallas County, and on Big and Little Mulberry Creeks in Autauga County, and obtained from well borers many notes of their occurrence, and conjectured that they belonged to a formation anterior to the Cretaceous. I had seen the same clays in 1871 on the road between Tuscaloosa and Eutaw, without reaching any decision as to their age. In August, 1883, upon the joint excursion of which this paper is the record, we had the satisfaction of observing every outcrop of these beds along the Tuscaloosa River below Tuscaloosa, and in the autumn of 1884, at the joint expense of Mr. T. H. Aldrich and the Geological Survey of Alabama, Mr. D. W. Langdon, jr., undertook an excursion through Bibb County along the Cahaba River, for the purpose of studying this formation there.

In the summer of 1885 the writer had the opportunity of examining many exposures of these clays and sands in the interior of Tuscaloosa, Hale, Bibb, and Autauga Counties.

In the early part of 1886 we found in the city of Tuscaloosa a fine exposure of dark gray, laminated clays, full of leaf impressions, which promise to furnish the means of determining definitively the age of the formation.

Some leaf impressions collected by Mr. Langdon and the writer in Bibb County were submitted to Professor Leo Lesquereux. One of these was considered by him to be referable to the genus *Podozamites*, with affinities to *P. lanceolatus* and *P. distans* of the Trias or Rhætic, and with still closer affinities to *P. pulchellus* Heer, from the Jurassic of Spitzbergen. Professor Lesquereux remarks: "I have found some species of the genus in the Cretaceous, but none with leaves of the same form as yours. The *P. pulchellus* has, like your leaf, distinct, coarse, somewhat distant primary nerves, separated by thin, punctate ones."[1] This leaf impression, so far as it goes, appears thus to confirm the evidence afforded by the *Ceratites* of Professor Harper, and the leaf impressions of Professor Winchell in so far as these indicate a pre-Cretaceous age for the formation.

This evidence, unfortunately, is not decisive. The plant remains found by Professor Winchell were not determined even generically; while the specimens of *Ceratites* were not found in situ in the beds in question, but "on a sand bank in the middle of the river * * * [in the area of known Cretaceous rocks] among other evidently Cretaceous fossils,"[2]

[1] Six (Rep. U. S. Geol. Surv. Terr., Vol. VIII, pp. 27-30, 1883).
[2] Proc. Acad. Nat. Sci. Phila., Vol. VIII, p. 126, 1856.

and at least one of them has since been pronounced, by no less competent an authority than Meek, "to be a worn specimen of the old genus *Ammonites*."[1]

Some better specimens from the city of Tuscaloosa were determined recently by Professor Lesquereux. They all point to the Cretaceous age of these beds, although the evidence is not yet conclusive.

In view of the diversity of opinion indicated by the foregoing review and of the paucity of organic remains in the Potomac formation and correlative deposits on the Atlantic slope, and in view of our uncertainty as to the exact equivalence of the deposits exposed on the Tuscaloosa River, we are unwilling to express ourselves decidedly as to the age of the formation to which they belong, though we incline to the belief that it is Cretaceous.

Since the formation to which the purple clays and associated strata belong is clearly distinct from those already recognized and named in Alabama and since it cannot be co-ordinated with certainty with any other formation in this country, it seems desirable that it should receive a specific designation. We therefore propose for it the name Tuscaloosa formation, after the name of the city at which and the river along which its typical exposures occur.

The stratigraphic relations of the Tuscaloosa formation may be seen by reference to the general section (Plate XXI, p. 185). In constructing this part of the section we have assumed a uniform dip towards the southwest of about forty feet to the mile. The indicated thickness is, accordingly, only approximate.

Rock Bluff.—Between Big Log Shoals and White's Bluff no rocks are seen along the river banks, except at Rock Bluff, where a pebbly conglomerate with ferruginous cement forms a bluff and, lower down the river, a rocky reef. This rock is underlaid by a gray or bluish clay. The position of this stratum is about seventy-five feet below the lowest of the Eutaw beds as exposed at Big Log Shoals.

At *White's Bluff* we see the first of a series of purple and mottled clays with interstratified sands, which occur at intervals as high up the river as Mrs. Prince's Landing, near Carthage. At the lowest estimate, these clays and sands are 275 feet in thickness.

In detail, the sections exposed along the river, in geologically descending order, are as follows:

(*a*) *Section at White's Bluff, Greene County, Tuscaloosa River.*

1. Purple clay, mottled with irregular patches of gray clay, both purple and gray portions sandy .... 10 feet.
2. Micaceous sands of light, nearly white color .... 1 foot.
3. Light colored sands, with little or no mica .... 14 feet.

[1] Rep. U. S. Geol. Surv. Terr., Vol. IX, p. 40, 1876.

A few miles higher up the river the same beds are again seen at *Steele's Bluff*, as follows:

(b) Section at Steele's Bluff, Tuscaloosa River.

1. Purple and mottled clays ....10 feet.
2. Light colored, often nearly white, coarse grained sands, holding a few small pebbles in places; the pebbles mostly of chert, not quartz.............10 to 12 feet.

The sands in the above section are in places strongly cross bedded and on exposure to the atmosphere show a tendency to harden into a pretty firm sandstone, which is, however, quite friable and easily rubbed down between the fingers after the thin outside coating of harder material has been removed.

At *Battle's Landing* there is a thin bed of ferruginous sandstone, extremely hard and firm and very similar to the ferruginous rocks so often formed in the drift beds.

At *Williford's Landing* the purple clay shows from the water's edge about ten feet in thickness, and over it occur second bottom or river deposits. Between the two a great number of bold springs of very pure water break out. An artesian well, said to be 400 feet deep, was bored at this place thirty or forty years ago, but no record of the boring is now to be had. The water flows out at the top and is not salty. This is the farthest north of any of the artesian wells of Middle Alabama. The locality is Sec. 31, T. 24 N., R. 4 E., in the lower edge of Tuscaloosa County.

Just above Williford's Landing and at *Bealle's Landing* there are reefs of rock forming shoals at low water. These rocks are sandstones and conglomerates, with ferruginous cement, similar to that already noticed at Battle's Landing.

We see the last outcrop along the river of the purple mottled clays at *Mrs. Prince's Landing*,[1] where they are about six or eight feet above the water's edge.

Between Mrs. Prince's Landing and Tuscaloosa the immediate banks of the river are with few exceptions formed by the loose materials of the second bottom deposits. At one or two places, however, given below, appear exposures of more ancient rocks. With a uniform dip of the strata, the distance between Mrs. Prince's Landing and Tuscaloosa would represent a thickness of more than five hundred feet, only forty or fifty of which are at all exposed along the river.

Saunders's Ferry.—At or near Saunders's Ferry, just below the Twelve Mile Rock, there is a fine exposure made by a landslide. Here are seen about thirty to forty feet perpendicular of thin, laminated clays and sands of a dark gray color, containing no recognizable fossils, but many small fragments of lignitic matter. Very similar beds have also been noticed by myself on the road from Tuscaloosa to Carrollton.

[1] They may be seen, however, above Mrs Prince's in many places, in the hills a few rods back from the immediate banks of the river. See section (c), next page.

At the time of my subsequent visit to this locality certain overlying strata omitted in 1883, because considered to be a part of the drift, were added, as well as some beds, nearer the water level, at that time hidden by alluvial deposits. The full section is as follows:

(c) *Section above Saunders's Ferry, Tuscaloosa River.*

1. Rather massive clays of greenish and purple colors, breaking with conchoidal fracture. On drying, these clays become hard and rock-like, resembling then, except in color, some of the claystones of the Buhrstone formation. These clays when wet soften and slide down the slopes, covering them completely in places. In this clay we find many rounded masses of ferruginous and silicious matter of oölitic structure. Thickness of the clays .... 40 feet.
2. Laminated, sandy clays, gray, with sand partings .... 5 feet.
   This bed is rather more coherent than the underlying and forms a slightly projecting or overhanging ledge.
3. Gray, cross bedded sands, with partings of clay along many of the planes of false bedding .... 25 feet.
   This and the preceding might readily be considered together as one member, more clayey in the upper five feet and sandier below, and this is our grouping of 1883. In these beds we find a good deal of lignitic matter and some leaf impressions very well preserved.
4. Slope or bench forty to fifty feet wide, covered by red clay and sands, slidden down from No. 1 and washed out of Nos. 2 and 3 .... 3 feet.
5. Gray or whitish, cross bedded sands, forming the immediate bank of the river. 15 feet.
6. Blue, micaceous sands to water level .... 5 feet.

This section of 140 feet is undoubtedly of Tuscaloosa materials.

At *Venable's Landing* there is a sandstone bluff 15 to 20 feet high, formed of bluish, micaceous sands indurated into a tolerably firm rock in places. The bedding planes of this rock are strongly ferruginous and numbers of chalybeate springs break out from the sides of the bluff.

About five and a half miles below Tuscaloosa there are to be seen at the water's edge some rocks which consist of sandy clays somewhat indurated. These clays are interstratified with thin beds of lignitic matter, with black scales resembling graphite disseminated through it. The lignitic matter consists of indistinguishable impressions of leaves and stems, and occasionally throughout the mass are nodules of iron pyrites, and not unfrequently fragments of stems lignitized or converted into charcoal, coated externally with a thin shell of pyrite.

In the banks of the branch at the University of Alabama there is a very similar small remnant of the Tuscaloosa formation, mottled clays, embedded in the red loam. The same, mottled purple and gray, appear at several places along the road leading from the university to the city of Tuscaloosa and in the gullies back of the city toward the river. In many of these localities the clays have evidently been partly redistributed, drift fashion, but in one or two places we see the undisturbed beds, consisting of dark bluish gray, nearly black clay, in laminæ (half an inch thick), separated by partings of white sand, six or eight feet thick, with white and yellowish, strongly cross bedded sands underlying them. It

[It i]s difficult to determine the thickness of these sands, as they are so hid[d]en by the débris from above, but it is not less than 20 feet.

In one of the gullies back of Tuscaloosa we get the following section:

(d) Section in Tuscaloosa.

[1]. Pebbles, sand, and red loam of the Drift, forming the plateau on which the city of Tuscaloosa stands ....15 feet.

[2]. Light gray, somewhat massive clays, mottled with yellow, but becoming laminated below ....3 feet.

[3]. Dark blue, nearly black, laminated clays, laminæ half an inch thick, separated by thin partings of white sand. The clay contains the leaf impressions which have been examined ....3 feet.

[4]. Yellowish gray, laminated clays, also containing a few leaf impressions, of rather variable thickness..2 feet.

[5]. Strongly cross bedded, yellowish or nearly white, sharp sand, with a few streaks of clay irregularly distributed through it. Thickness uncertain, but not less than..20 feet.

We cannot say what lies below the sands, since the strata of this [f]ormation about Tuscaloosa have suffered a great amount of denudation [b]y erosion and their outcrops appear only here and there. The erosion [h]ollows have been filled in with pebbles and sands of the Drift, often to [t]he depth of 50 or 60 feet. These circumstances and the fact that the [c]lays themselves have in places been broken up and redeposited in [l]umps among the drift pebbles have caused this formation to be over[l]ooked or confounded with the Drift. The dark gray, laminated clays above mentioned contain many beautifully preserved leaf impressions, which are now being studied and which will probably fix definitely the age of the formation.

It will thus be seen that the exposures along the river give us an insight into the composition of only a very small proportion of the strata which underlie the purple clays.

3. OBSERVATIONS FROM 1883 TO 1885 OF OCCURRENCES AWAY FROM THE TUSCALOOSA

The observations made since 1883 by each of us independently and by D. W. Langdon, jr., of the Geological Survey of Alabama, have confirmed our first conclusion as to the relative positions of the various strata of this formation, and at the same time have added to our knowledge of its component parts.

The observations of Mr. Johnson have extended over parts of Autauga and Dallas Counties, on the waters of Mulberry Creek, and, in 1884, to Tishomingo and Itawamba Counties, in Mississippi. Those of the writer and of Mr. Langdon have extended over parts of Tuscaloosa, Hale, Bibb, and Autauga Counties.

To these observations are added those of Prof. A. Winchell, who describes the formation under discussion in the following terms:[1]

[1] Proc. Am. Assoc. Adv. Sci., Vol. X, Part II, p. 93, 1856.

At about eight miles above Eutaw the shale becomes softer, the lamination disappears, and we have beds of light clay, mottled curiously with blue, red, and yellow, reminding one forcibly of the Keuper of the Germans. More than this, we find along the roadsides and the margins of ravines in the upper part of Greene County large masses of red and poikilitic sandstone, exceedingly compact, and used for underpinning buildings. Add to this that very many of the artesian wells in Greene County, which penetrate these beds, furnish a constant flow of salt water, showing the occurrence of local deposits of salts, while the deepest borings have brought up abundance of quartzose pebbles, and we have four well established facts compatible with the supposition of the Triassic age of these beds, without mentioning the occurrence of vegetable remains, some specimens of which appeared to me indistinctly allied to stems of *Equisetites*.

These beds continue without much change to the very suburbs of Tuscaloosa; and a very good section is seen at Foster's Ferry, within a few miles of town.

The almost total absence of organic remains from these shaly and poikilitic deposits renders the determination of their age extremely uncertain.

It seems probable that the red sandstone mentioned by Professor Winchell is the same as that occurring at Battle's Gin, on the river, and at Havana, presently to be described.

On going by land from Tuscaloosa to Eutaw, on the western side of the river, in 1886, we have been able to repeat the observations of Professor Winchell. Two miles west of Saunders's Ferry and about ten miles west of Tuscaloosa, the road passes by the edge of a great gully washed out of materials of the Tuscaloosa formation. This gully is of nearly 100 feet perpendicular depth, and the bottom slopes then very gradually down 40 or 50 feet more.

(*a*) *Section of gully 10 miles west of Tuscaloosa.*

1. Drift and red loam .... 10 feet.
2. Sharp, yellowish, cross bedded sands, with strings of light yellow, chert pebbles, subangular and in many cases showing casts of encrinital buttons and bryozoans and other sub-Carboniferous fossils .... 20 to 25 feet.
3. White and red, laminated clays of very irregular thickness, often discontinuous .... 5 feet.
4. Firm, yellowish sands .... 12 feet.
5. Bed of subangular, white and yellow chert pebbles, with sub-Carboniferous fossils .... 2½ feet.
6. Red clay in irregular beds or pockets .... about 3 to 4 feet.
7. Yellowish white sands, with thin streaks of pebbles .... 8 feet.
8. Red clay and sand .... 1 foot.
9. Strongly cross bedded, yellow sands, with thin, irregular sheets of clay following some of the lines of false bedding .... 35 feet.

Below this, cross bedded sands with clay partings continue to the lowest part of the gully, probably 40 feet below the above section.

From this place down to Knoxville nearly every hill reveals the materials of this formation, consisting mainly of yellowish and reddish, cross bedded sands, with clays (red and purple) sparingly interspersed. The section of the gully above given might be taken as typical of the strata exposed over this entire distance.

In places the sands are cemented by iron into quite firm sandstones, which are quarried for rough work. The rock can be easily cut when

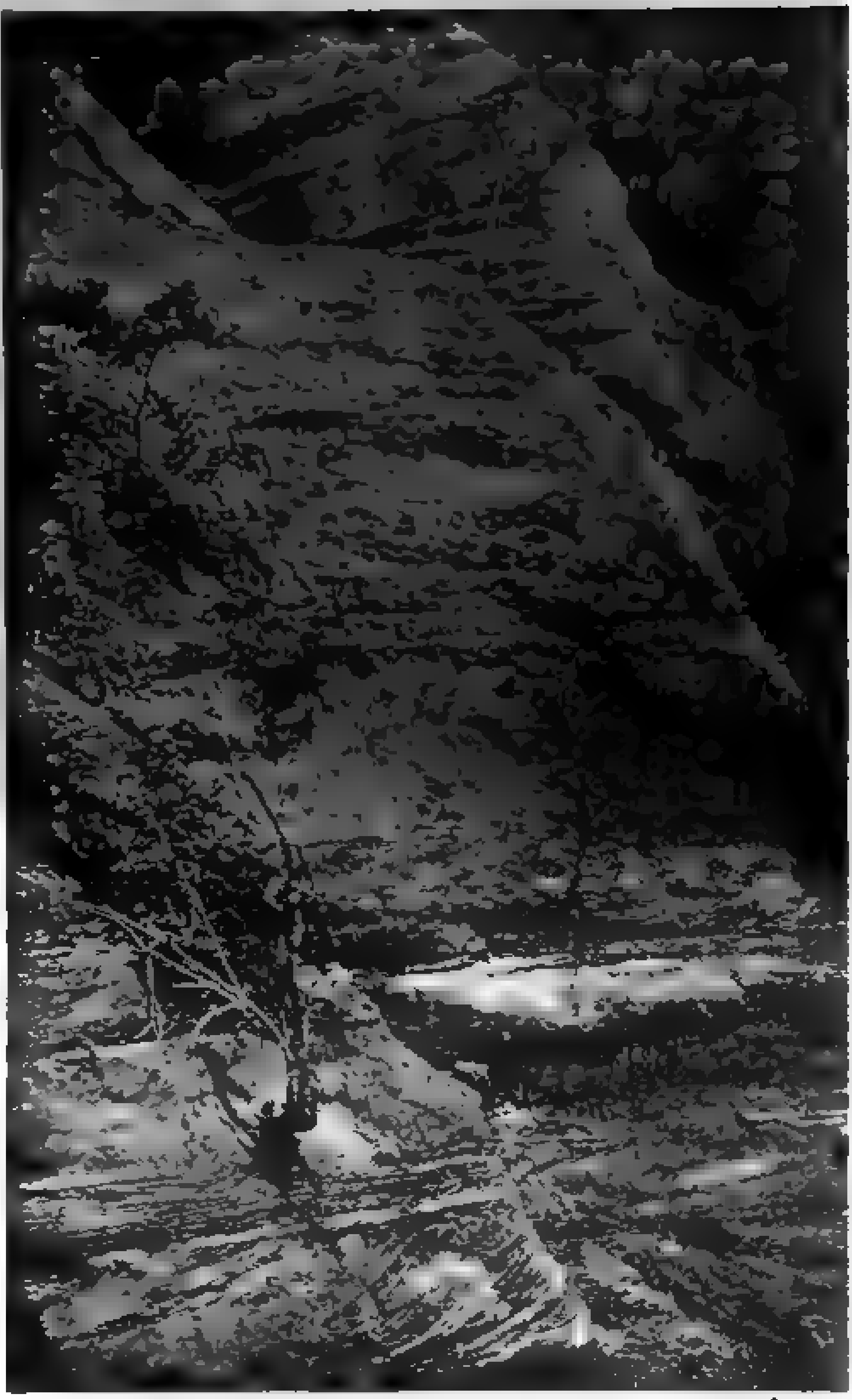
freshly dug, but it soon hardens on exposure. I am strongly inclined to believe that the red sandstones and conglomerates seen at Battle's Gin, above Williford's Landing, near Havana, &c., are bedded rocks of this formation; at any rate the constituent sands are of this age, while the induration into rocks by the ferruginous solutions may have occurred in comparatively recent times.

A short distance south of Knoxville we lose sight entirely of the red and purple clays which have been to us a characteristic of the Tuscaloosa formation, and begin to encounter the glauconitic, cross bedded sands, laminated clays, and other materials which we have classed with the Eutaw formation. If we assume a dip of 30 or 40 feet to the mile, estimating from the width of outcrop, there will be some 900 feet or more of the Tuscaloosa and 300 to 400 feet of the Eutaw formation. In both, these materials have been deposited under almost identical conditions, except that at the base and at the summit of the Tuscaloosa formation we find heavy beds, 40 feet or more in thickness, of massive clays of red, purple, and greenish colors, and also sparingly interspersed through the whole of the formation are thinner beds of similar clays. No beds of this character have been observed in what we have called the Eutaw formation, the only beds of which, other than sands, are thin, laminated, gray clays, with partings of sand.

The pebbles of the Tuscaloosa formation are, as a rule, subangular, of chert, and in many cases fossiliferous; those of the Eutaw, well rounded, of quartz, and non fossiliferous, so far as our observations go. The cross bedding of the sands in the Tuscaloosa formation is much less pronounced than in the Eutaw, as if effected in less rapidly flowing waters. The two formations are further alike in the circumstance that their only fossils are leaf impressions and lignitized trunks, the marine fossils in the sands just below the Rotten Limestone characterizing the transition beds which have been named "Tombigbee Sand" by Dr. Hilgard.

One may well hesitate to separate very widely these two formations, whose strata were deposited continuously and under very similar conditions and contain the same character of fossil remains, until a thorough study of the leaf impressions and other fossils shall have established their positions in the geological scale. In our southern post-Tertiary Drift, our Eutaw, and our Tuscaloosa formations we have three groups of very similar strata, whose distinctive characters it is difficult, if not impossible, to describe in words, since there are cross bedded sands with interspersed sheets and beds of clay and pebbles in all three; yet in the field the differences are so easily recognized in the topography, the timber, in the color and other qualities of the soils, &c., that we are never long in doubt as to which formation we have under consideration.

A few miles south of the village of Havana on the Greensborough road begin the yellowish red, glauconitic, cross bedded sands of the Eutaw group, which extend down to Greensborough.



NEAR HAVANA, HALE COUNTY

Just north of the first appearance of these cross bedded, glauconitic sands, near the residence of Hon. A. M. Avery, there are several very deep gullies near the road where the upper beds of the Tuscaloosa formation are beautifully exposed (Plate IX). These beds are as follows:

(*b*) *Section two miles south of Havana, Hale County.*

1. Red surface loam, forming exceedingly fertile soil ....10 to 15 feet.
2. Yellow sands and pebbles, conformable in stratification with the underlying strata ....10 to 12 feet.
3. Purple and pink, micaceous, argillaceous sands, most beautifully cross bedded, 20 to 30 feet.

That these deposits lie very near the summit of the Tuscaloosa formation is evident from the fact that the cross bedded, glauconitic sands of the Eutaw formation occur at the surface only a very short distance to the southward. The red loam forming the uppermost of the section resembles in some degree the usual red loam of much of the southern part of the State, except that it is of much deeper color and apparently more fertile than most of these loams. It may be derived from the disintegration of the glauconitic sands of the Eutaw formation or from the uppermost of the Tuscaloosa formation. The pebble bed No. 2 resembles also in some degree the pebble beds of the Drift, but as it is entirely conformable in stratification with the underlying beds (a circumstance of rare occurrence in the Drift) I am inclined to consider this bed also as a part of the Tuscaloosa formation. The sands No. 3 differ from anything which occurs in the Drift, and I have seen the like only at one other place, viz, on Mulberry Creek, in Autauga County, near the residence of Hon. James W. Lapsley.

North of Havana the underlying beds of this formation are exposed in the following order: At Havana, and appearing at intervals for several miles northward, there is a thick bed of ferruginous conglomerate, best seen in a ravine back of the town of Havana, where it forms perpendicular bluffs ten to twelve feet in height at the top of the ravine. Large masses of the rock have split off from time to time and have rolled down into the gorge below.[1] It has been impossible thus far to determine whether to refer this conglomerate to the Drift or to the Tuscaloosa formation. Its great extent and its persistence seem to favor the supposition that it belongs to the older formation, yet it is in appearance quite similar to a conglomerate of very common occurrence in the

[1] Underneath the ledge of rock shallow caves have been washed out, and in these flourish several rare ferns, especially *Asplenium ebenoides* Schw., which was discovered here by Miss Julia Tutwiler and is interesting from the fact that it is known to occur elsewhere only along the banks of the Schuylkill River. Besides this fern, there are *Camptosorus rhizophyllus* or walking leaf, *Trichomanes radicans*, and *Aspedium marginale*. The appearance of this conglomerate and the ferns growing in the shallow caves beneath it recall very forcibly the Carboniferous conglomerate which forms the surface over so great a part of the counties of Marion and Winston.

Drift everywhere. I do not know, however, of any similar Drift formation approaching this in the thickness of the rock.[1]

On the south side of Big Sandy Creek we get again a very good section of the purple clays which form the lower members of the Tuscaloosa formation, as follows:

(c) Section on Big Sandy Creek, Tuscaloosa County.

1. Purple and mottled clays like those occurring at Steele's Bluff, on the Tuscaloosa River ....30 feet.
2. Light yellow sands, with pebbles, also similar to those seen at the above named locality and at White's Bluff ....10 to 15 feet.
3. Gray, laminated clay, inclosing a lignitized tree trunk, at base of hill...4 to 5 feet.

Farther along the road the thickness of the purple clays is seen to be at least 50 feet and they crop out along the hillsides for a good many miles. It is easy to recognize them even without close examination, for wherever they come to the surface in the roads it is necessary in wet weather to lay down a causeway, since the tenacity of the clay is so great that the road would otherwise be impassable.

About seven and a half miles from Tuscaloosa, where the Greensborough road crosses Little Sandy Creek, we get an exposure of what we suppose to be still lower members of the formation. This section was first examined in 1884 by Mr. Langdon. It is as follows:

(d) Section on Little Sandy Creek, Tuscaloosa County.

1. Micaceous, yellow sands, including a thin streak of gray, lignitic clay, with small pieces of lignitic matter....................................10 inches.
2. Gray, laminated clays, highly micaceous ....6 feet

Between the two branches of Sandy Creek the purple and mottled clays appear upon nearly every hillside. North of Little Sandy Creek we see no more of the strata of this formation along this road.

In November, 1884, D. W. Langdon, jr, made a study of this formation in Bibb County, and in 1885, in company with Mr. Langdon, I examined its outcrops in the western part of Autauga County and the adjoining parts of Dallas and in those parts of Bibb and Tuscaloosa Counties lying between the towns of Tuscaloosa and Randolph.

In the western part of Autauga County, near the post office, Vineton, there are several exposures of the upper beds of the Tuscaloosa formation, shown in the following sections:

(e) Section near Col J. W. Lapsley's, near Vineton, Autauga County, No. 1.

1. Stratified clays of white, pink, and purple colors, interlaminated with thin sheets of yellow sands, the lower 8 feet of this bed have a larger proportion of sands..10½ feet.
2. Gray, laminated clays, with partings of purple sands ....5 feet.
3. Yellowish white, laminated clays, with purple and other bright colors on the dividing planes, 5 feet showing; but the same beds appear to continue down the hill for at least 10 feet farther ....15 feet.

[1] A careful comparison of the pebbles should be made.

At another locality near Colonel Lapsley's, in a gully, we see the following section:

(f) Section near Col. J. W. Lapsley's, No. 2.

1. Yellowish sands, beautifully cross bedded ....4 feet.
2. White and pink clays, interbedded with yellow sands...........................10 feet.

Along the road leading from Colonel Lapsley's to the railroad station (Jones's switch), we get another section of the strata represented in the first section above, together with some underlying beds. In the upper part, these beds, being exposed along a road, are much stained, so that it is impossible to correlate them, foot by foot, with those exposed in Section 1, although they have about the same altitude and are distant from each other only about half a mile.

Below some 40 or 50 feet of red loam containing fragments and bowlders of ferruginous sandstone, such as characterizes the Drift formation we get the following section:

(g) Section near Col. J. W. Lapsley's, No. 3.

1. Purple clays, interbedded with reddish sands.......................................6 feet.
2. Mottled (red and yellow), sandy clays, partly obscured by overlying drift, pebbles, and sands..12 feet.
3. Red sands, containing small, lenticular bits of yellow clay ....5 feet.
4. White and yellow laminated clays...6 to 8 feet.
5. Strata not seen ....10 to 15 feet.
6. Variegated, micaceous, and slightly argillaceous sands, strongly cross bedded; colors, bright and sharply defined, pink, dark purple, yellow, and red..5 to 6 feet.

The strata of bed No. 6 are identical in appearance and in composition with the variegated sands exposed in the gullies at Mr. Avery's, near Havana, in Hale County, above described. I did not notice here the yellow sands with pebbles immediately over the variegated sands, but they may have been in the division No. 5, here obscured by surface materials.

Across a small ravine from this section, the yellow sandy clays have been washed for yellow ocher, the beds occupying about the same position as Nos. 2, 3, and 4 of the preceding:

(h) Section at the ocher beds, near Vineton.

1. Yellowish red, cross bedded sands, inclosing thin streaks of purple clay ....6 feet.
2. Yellow, sandy clay, from which the ocher is obtained.............................16 feet.

The sand makes about 80 per cent. of the above bed, and the ocher is obtained from it by washing. The ocher is of excellent quality and of bright yellow color.

Nearly 100 feet below the lowest of the beds of Section 3 we see in the banks of Mulberry Creek, just below the iron bridge, the following section:

(i) Section on Mulberry Creek, near Vineton, Autauga County.

1. Mottled, purple clays, similar to those at Steele's Bluff, on Tuscaloosa River.5 feet.
2. Yellow, cross bedded sands ....3 feet.
3. Mottled clays, sandy below...5 feet.
4. Grayish white, micaceous sands, with irregular patches of red and yellow colors ....4 feet to water.

This whole section is identical in appearance with that seen at White's Bluff and at Steele's Bluff.

From Vineton up to Randolph very little can be seen of the strata of the Tuscaloosa formation until within three miles of the latter place, where the dark purplish gray clays, which seem to lie near the base of the formation, are encountered. These clays are undistinguishable from those above described between the two branches of Sandy Creek in Tuscaloosa County.

Between Randolph and Centreville we get several very good sections of the beds under consideration, as follows:

(j) Section at Soap Hill, 7 miles east of Centreville, Bibb County.

1. Purple, mottled clays at summit of hill ....5 feet.
2. Clayey sands in several ledges ....10 feet.
3. Cross bedded, yellowish and whitish sands, traversed at intervals by ledges of sandstone formed by the induration of the cross bedded sands....................30 feet.
   The thickest of the above sandstone ledges is about 3 feet.
4. Laminated, gray clays, with partings of sand ....10 feet.
5. Alternations of laminated, gray clays and cross bedded sands in beds of 12 to 18 inches thickness .... 40 feet.
6. Yellowish, cross bedded sands, with clay partings ....20 feet.
7. Laminated, gray, sandy clays, containing a few leaf impressions, which are, however, not distinct enough as a rule to permit perfect identification..10 to 15 feet.
8. Grayish white sands ....8 feet.

In this section the first three members are best seen on the eastern slope of the hill and Nos 7 and 8 in a gully on the eastern side of the hill. The intervening members are most clearly exposed on the western descent of the hill, nearly a mile from the first locality.

Between four and five miles east of Centreville a part of the preceding section is repeated.

(k) Section 4 to 5 miles east of Centreville, Bibb County.

1. Gray and reddish, sandy clays ....15 feet.
2. Ledge of sandstone showing cross bedding ....3 feet.
3. Whitish sands and clays ....4 feet.
4. Nearly white, cross bedded sands ....25 to 30 feet

The hill in the eastern part of the town of Centreville contains a good deal of reddish, mottled clays, probably of this formation. These clays may be seen again about half way between Centreville and Scottsville, where they appear to overlie the strata of the Lower Silurian and Carboniferous formation. Between Scottsville and Tuscaloosa these beds are seen at several localities.

About twelve miles east of Tuscaloosa the grayish purple clays similar to those described between the two branches of Sandy Creek appear in many places along the slopes of hills where they are laid bare by the road.

(l) Section 10 miles east of Tuscaloosa.

1. Ferruginous sandstone in sheets ....6 to 8 inches.
2. Variegated, clayey sands holding small pieces of purple clay. The sands show chocolate, purple, red, and yellow colors ....6 to 8 feet.

3. Purple clays, with partings of sand; similar to the purple clays south of Tuscaloosa .... 10 feet.
4. Ledge of ferruginous sandstone .... 1 foot or more.
5. Laminated, gray and yellow, sandy clays or clayey sands, yellow at top and shading into gray at bottom .... 6 to 8 feet.
6. Lignite, with pyrite nodules .... 2 to 6 inches.
7. Dark gray, somewhat massive clays, becoming lighter below .... 6 to 8 feet.
8. Strata obscured by washings from above .... 20 feet.
9. Purple clays at base of hill .... undetermined.

In some places near this, five feet of purple clays are seen overlying No. 1 of the section.

About nine miles east of Tuscaloosa about 30 to 40 feet thickness of purple clays is seen along a hillside. In these clays there are two ledges of ferruginous sandstone or, perhaps more properly speaking, of sandy iron ore. The clays are a mixture of purple and yellow and appear to form the lower strata of the hill for 20 or 30 feet below those above described. The iron ore which covers so much of the slope of this hill is somewhat sandy, occasionally quite pure and compact, giving a red streak. It differs very materially from the usual limonite of the valleys.

At the Box Spring, about five miles east of Tuscaloosa, the railroad cut exposes 6 to 8 feet of laminated, gray clays marked with purple streaks. Immediately above these is a very persistent ledge of ferruginous sandstone and over that 10 or 12 feet of drift and loam of recent date.

About four miles east of Tuscaloosa we see the summit of a rounded mass of the strata of this formation, consisting of 2 or 3 feet of purple, gray, and variegated, laminated clays, underlaid by about the same thickness of cross bedded sands. This exposure lies plainly unconformably embedded in the red loam of the Drift.

4. OBSERVATIONS IN MISSISSIPPI.

In 1884 Mr. Johnson, on his reconnaissance of Tishomingo and Itawamba Counties, in Mississippi, saw beds of lignite and tough, laminated clays which he, at the time, referred to a formation below the Eutaw (our Tuscaloosa). This lignite was traced by him the whole length of Reed's Creek (between the Tombigbee at Fulton and Bull Mountain Creek). At several localities, viz, at Maxey's Old Mill, Sec. 9, T. 10 S., R. 9 E., he collected many fine leaf impressions. The lignite here was two feet thick. At Reed's Mill and at Chaney's, Secs. 20 and 17, in T. 10 S., R. 9 E., many phytogene fossils were collected, and these localities were remarkable for the fine, jet-like appearance of the lignite. A jet of this kind was also found by Mr. Langdon in Centreville, Bibb County, Alabama. At Barnard's Bluff on the Tombigbee, the lignite appears again embedded in characteristic clays of the Tuscaloosa formation.

Mr. Johnson also calls attention to the gravel beds which occur in this part of Mississippi, and which, according to my observations, have their counterpart in Marion, Colbert, and Franklin Counties, Alabama.

The materials of these gravel beds are mostly cherty, subangular, and quite different from the usual quartz pebbles of the Drift. Associated with these are the so called kaolin beds and the deposits of pulverulent silica. The pebbles as well as the silica are evidently derived for the most part, if not entirely, from the fossiliferous chert of the sub-Carboniferous formation of that region. Mr. Johnson expresses the opinion that these pebble beds of chert underlie the newer, stratified, glacial drift deposits without being a part of the same. Wherever the pebble beds occur in the Cretaceous or sub-Cretaceous clays of Tishomingo and Itawamba Counties, in Mississippi, there is a prevalence of these cherty characteristics. In this connection we may also refer to the fact that the pebbles seen in the Tuscaloosa sands at White's Bluff and at Steele's Bluff on the Tuscaloosa were of chert and not of quartz.

IV. SUMMARY OF THE LEADING FEATURES OF THE CRETACEOUS STRATA OF ALABAMA. (PLATE XXI.)

Under this heading, while making a distinction between the two, we include both the strata of undoubted Cretaceous age and those of as yet undetermined but probably Cretaceous age.

CRETACEOUS STRATA.

The whole thickness of unquestioned Cretaceous rocks in the western part of Alabama, according to our measurements and estimates, is between 1,550 and 1,575 feet, and the group has been divided into three formations, which are (1) the Ripley, (2) the Rotten Limestone, and (3) the Eutaw.

1. *The Ripley formation.*—We cannot give the absolute thickness of this formation, but it will in all probability fall between 250 and 275 feet. The strata are, first, 55 to 60 feet of yellow sands,[1] in some localities containing many Cretaceous shells, followed by 100 feet of dark gray, nearly black, micaceous, sandy clays or clayey sands, traversed by hard ledges of similar materials, and, along the two rivers at least, not prolific of fossil remains. Then 30 to 35 feet of bluish, argillaceous limestones, with great numbers of Cretaceous fossils, which are, however, mostly in the form of casts and generally phosphatic. Below this, again, a mass of sands (60 feet or more) of various colors, with indurated bands of sandstone running through it.

2. *The Rotten Limestone.*—In this we have the most massive of the calcareous formations of Alabama, outside of the Paleozoic. The thickness is about 1,000 feet, and there is surprising uniformity in the material, which is an impure, argillaceous limestone, merging in places into a calcareous clay. Where the clay predominates, we usually find the

[1] We have recently found conclusive evidence that the yellow sands are merely a modification produced by oxidation of the gray sandy clays next below.—E. A. S.

greatest abundance and variety of fossils. The strata of the Rotten Limestone form the bluffs along great stretches of both rivers.

3. *The Eutaw formation.*—This formation has a thickness of not less than 300 feet. At the base of the Rotten Limestone we find some 20 to 25 feet of calcareous sands and greensands, in part strongly phosphatic, containing a large number of fossils, many of which are in the form of phosphatized casts. This bed forms a transition between this and the next succeeding formation. We place it with the Eutaw formation for the sake of convenience, with the remark that an examination of the fossils may hereafter show that it is more closely related to the Rotten Limestone.

Below these phosphatic sands are yellowish, cross bedded sands, 40 to 50 feet, and laminated, blue clays alternating with glauconitic sands for 40 feet more. The rest of the strata, to the base of this division, consist of laminated and cross bedded sands and laminated clays in many alternations, interbedded at intervals with lignitic strata consisting of lignitized twigs and trunks of trees, but not, so far as yet known, of beds of lignite. With these are one or two thin beds of pebbles. As before stated, the exact thickness cannot be given.

STRATA OF UNDETERMINED AGE, PROBABLY CRETACEOUS.

The Tuscaloosa formation.—Below the lowermost of the undoubtedly Cretaceous beds is found a great thickness of clays and sands of as yet undetermined age. These appear at intervals along the banks of the Tuscaloosa or Warrior River from Big Log Shoals up to the city of Tuscaloosa. Assuming a uniform dip of some 40 feet to the mile, the thickness of this formation will be about 1,000 feet. We cannot as yet give the order of succession of the various strata, which are mottled, purple, and gray clays, yellowish and gray sands, pink and light purple sands, and thinly laminated, dark gray clays, which contain impressions of leaves in considerable numbers and sometimes in a state of preservation perfect as to form and markings.

V. UNDULATIONS AND FAULTS IN THE TERTIARY AND CRETACEOUS STRATA OF ALABAMA.

TERTIARY STRATA.

The average seaward dip of the Tertiary strata of Alabama is about twenty-five or thirty feet to the mile, but there is at many points a wide departure from this uniformity. Professor Tuomey appears to have been the first to direct attention to this circumstance. In speaking of the Buhrstone at the Lower Salt Works, in Clarke County, he remarks:

> We have here, then, an interesting example of the sinking of strata below the surface and of their rising again. The beds exposed at Baker's Bluff, and still higher on the river, as well as on Bashi Creek, after being depressed beneath Saint Stephens and a portion of Clarke County, make their appearance again at this locality, and probably still farther west.[1]

[1] First Bien. Rep. Geol. Ala., p. 150, 1850.

As intimated in another part of the present publication, these observations of Professor Tuomey were confirmed by us in 1853, and my subsequent investigations have further shown the existence of more than one well marked fold in the strata of this part of the State.

On another page we have said that the Buhrstone rocks which dip below the surface a short distance south of Wood's Bluff, in Clarke County, rise again at Hatchetigbee Bluff and at Jackson, and from this place an almost continuous outcrop of these rocks may be followed southward as far as the Lower Salt-Works. These points appear to mark the summits of at least two distinct anticlines, and a third is marked by Lower Peach Tree, on the Alabama River, while the unequal surface distribution of the beds of the Lignitic formation, lying to the northward of the localities above named, leads one to suspect the existence of several other folds, notably one involving the black clays of the Black Bluff group along the Tombigbee River, another concerning the *Gryphæa thirsæ* beds in the central part of Marengo County and in the Grampian Hills region of Wilcox County.

We have determined approximately the limits of the Hatchetigbee anticlinal and of the Lower Peach Tree fold and its associated fault in the immediate vicinity of the Alabama River. We have also followed a line of uplift from near Jackson down to the Lower Salt Works in Clarke County. In what follows we give some details of the observations on which our knowledge of these undulations is based and we also append a few notes concerning the irregularities in the surface distribution of the Buhrstone and the underlying beds of the Lignitic in Monroe and Conecuh Counties.

(1) THE LOWER PEACH TREE ANTICLINE.

In ascending the Alabama River we find the Wood's Bluff marl at the water level at Johnson's wood yard, a few miles below Bell's Landing. At the latter locality a marl bed, which is about 115 to 120 feet below the Wood's Bluff marl, and which we have called the Bell's Landing marl, is some 25 or 30 feet above water level. Nine miles farther up the river, at Lower Peach Tree, this bed is 100 feet above water level, while at Yellow Bluff, several miles still farther up the river, it is seen within 10 feet of water level, and the Wood's Bluff marl appears about 115 or 120 feet above it on the hillside immediately back of the river bluff.

Above Yellow Bluff the river makes a bend towards the southeast, so that the Wood's Bluff marl is not seen again along its banks in this direction; at Bethel, however, a few miles west of Yellow Bluff, we see the Wood's Bluff marl and the *Gryphæa thirsæ* beds, which are separated by at [illegible]0 and probably by over 300 feet of strata, coming to the [illegible] half a mile of each other and not more than 120 feet [illegible]y apart. This disposition of things appears to show that [illegible] Bethel there is either a very abrupt change in the angle

of dip of the strata or a stratigraphic break. I have examined the ground very carefully on several occasions, and have failed to see any evidence of high angle of dip, but, on the contrary, have obtained the clearest evidence of the existence of a fault of nearly 200 feet vertical displacement, traced from Bethel across the river to Black's Bluff, and it probably extends much farther in each direction from these limits. We shall call this the Bethel fault and give below some details of its occurrence.

The Lower Peach Tree fold.—The geographic limits of the Lower Peach Tree fold, so far as we have determined them, have been fixed by the following data: Across Choctaw County, the Wood's Bluff marl occupies a narrow strip of surface; at Wood's Bluff, on the Tombigbee, and at Cade's Bend, a mile or two above, it appears at the water level, showing a nearly horizontal position. This may be the beginning of the fold, which, beyond Choctaw Corner, eastward, broadens out till at the Alabama River it spreads over an expanse, north and south, of 10 miles or more. In the vicinity of the river, however, its occupation of the surface is not continuous, but the underlying beds of the Bell's Landing series come in and make the intervening country between its two exposures, the one south of Lower Peach Tree, the other in the vicinity of Bethel and Yellow Bluff. In its longer dimension, therefore, this fold appears to rise about the Tombigbee River near Wood's Bluff and to extend with constantly increasing elevation to the Alabama River, Lower Peach Tree occupying the summit of the roll, which has its widest cross section along the Alabama River. Eastward from this river, I have followed, with the exception noted below, a single outcrop only of the Wood's Bluff marl across Monroe County along the course of Flat Creek, and this is the continuation of the lower of the two outcrops of the bed above spoken of, as exhibited in Wilcox County west of the river and south of Lower Peach Tree, while, of the northern or Bethel outcrop, I have seen only one occurrence east of the river, viz, near Black's Bluff. This is no doubt in great measure due to the fact that there is on the eastern side of the river, opposite Yellow Bluff, a good deal of low country from which the older strata have been removed by denudation.

This fold involves, so far as concerns their surface outcrop, the Bell's Landing, the Wood's Bluff, and the Hatchetigbee series of the Lignitic, for the clays of the latter series are to be seen overlying the Wood's Bluff marl in the hills west of Yellow Bluff. I have not seen any evidence either of the broadening or of the duplication, by reason of this fold, of the outcrops of the Buhrstone rocks which immediately overlie the Hatchetigbee beds.

To summarize, we can trace this anticline in the direction of its axis from Wood's Bluff, on the Tombigbee River, across Clarke County, to the Alabama River, where it has its greatest elevation and its broadest cross section; beyond the river, eastward, we have traced [illegible]

Black's Bluff. The northern limit of this fold, in the vicinity of Bethel, is a fault of at least 200 feet displacement, length not ascertained, already mentioned above.

The Bethel fault.—To obtain a clear idea of this fault it is necessary to recall the stratigraphic relations of the several subdivisions of the Lignitic which it involves. The Wood's Bluff marl, with its indurated limestone bowlders and its characteristic fossils, is our best landmark. Above this marl lie the sandy clays of the Hatchetigbee section, 175 feet in thickness. These latter beds are only slightly concerned in the fault. Below the Wood's Bluff marl we have about 120 feet of sandy clays and clayey sands, the upper 75 feet of which hold several beds of lignite, and then another marl bed, the Bell's Landing marl. Below this marl we have at Lower Peach Tree about 100 feet of gray sandy clays containing two marl beds (Gregg's Landing marl being the upper of the two). In these sections, therefore, we have over 400 feet of strata, the exact relations of which are clearly seen at Yellow Bluff and at Lower Peach Tree.

The Nanafalia section consists at top of 50 feet or more of gray, sandy clays, showing a great tendency to indurate into hard rocks, resembling the Buhrstone, to which, for convenience, I give the name *pseudo-Buhrstone*. Below the pseudo-Buhrstone are at least 80 feet of sandy strata, characterized by the presence of *Gryphæa thirsæ*, and below these still, about 70 feet of cross bedded, glauconitic sands, with a few obscure fossils in the upper part, and a bed of lignite, from four to seven feet in thickness, near the base. As we have already intimated several times, we have seen no exposures which exhibit both the Lower Peach Tree beds and the pseudo Buhrstone, so that it has been thus far impossible to determine the dimensions of the gap between the base of the Bell's Landing (at Lower Peach Tree) and the summit of the Nanafalia section (at Gullette's Landing); and the Bethel fault, coming as it does exactly at this place in our geological scale, serves to complicate matters still more. In estimating the vertical displacement caused by the fault, there is always the unknown quantity embraced in this gap to be considered, and our estimates are to be taken as exclusive of this unknown quantity.

Following are given some details concerning the fault. At Bethel, SW. ¼ of Sec. 35, T. 12 N., R. 5 E., the Wood's Bluff marl occupies the summit of the hills, and about half a mile north we find the *Gryphæa thirsæ* beds. The Wood's Bluff marl may also be seen on most of the hills between Bethel and Yellow Bluff and at the latter place, and a line drawn from Bethel to Yellow Bluff will just about define the limit of the marl towards the east. As we descend towards the east from any of these hills, capped with the Wood's Bluff marl, we come directly, and usually within 50 feet vertical distance, upon the pseudo-Buhrstone, and 60 or 70 feet below that upon greensands holding *Gryphæa thirsæ*. Near Bethel towards the southeast then the fault brings

together, or rather within 50 feet of each other, the Wood's Bluff marl and the pseudo-Buhrstone, a displacement, taking no account of the gap between the Bell's Landing and Nanafalia sections, of more than 150 feet. At Yellow Bluff, as we have seen in foregoing pages, there are exposed all the strata from the Wood's Bluff down to the Bell's Landing marl. Up the river, within half a mile of the landing, this marl dips below the water level. Less than half a mile farther up the river, beds of *Gryphæa thirsæ* appear in the left bank. Here some of the beds overlying the Bell's Landing marl are brought together with *Gryphæa thirsæ* beds, a displacement, as before, of 175 feet or more. Again, across the river, on the plantation of Mr. James Tait, Sec. 24, T. 11 N., R. 6 E., near Black's Bluff, we find the Wood's Bluff marl forming the second bluff, about 100 yards from the river, while the lower beds of *Gryphæa thirsæ* marl, Nos. 10, 11, and 12 of the Gullette's Bluff section, make the immediate bank of the river. In this case the strata between Wood's Bluff and Bell's Landing marls (120 feet), those below the Bell's Landing marl at Lower Peach Tree (100 feet), the pseudo-Buhrstone (50 feet or more), and about 30 or 40 feet of the *Gryphæa thirsæ* beds have been engulfed, a displacement of not less than 300 feet, leaving out of account, as before, the gap mentioned. We have traced the fault from Bethel to Black's Bluff, a distance of 10 miles or more. Eastward from Black's Bluff, near where the Camden road crosses Gravel Creek, on Yankee Branch, a thick bed of lignite (4 feet or more) occurs immediately and to all appearances conformably below beds of *Gryphæa thirsæ*. The Coal Bluff lignite has above it some 60 feet or more of glauconitic sands, separating it from the *Gryphæa thirsæ* beds, so that this contact of two unusually widely separated beds (if this be the Coal Bluff lignite) could only be brought about by some kind of displacement. And lastly, at Black's Bluff we have a thick bed of lignite in contact with the *Gryphæa thirsæ* beds. From its close proximity to the Wood's Bluff marl (at the line of fault above described), one would be inclined to consider this as one of the lignites of the Wood's Bluff series but for its thickness. The certain identification of these lignites and their relations to the Bethel fault we have still to work out.

(2) THE HATCHETIGBEE ANTICLINE.

The axis of this fold, like that of the preceding, has a northwest-southeast direction. At the southeastern end and also at the northwestern it sinks gradually to the level of the undisturbed beds. It may be traced from near Nicholson's Store, in Choctaw County, across that county, through Bladen Springs, into the northeastern corner of Washington County at Hatchetigbee Bluff, and thence across the river for about ten or twelve miles into Clarke County. It is about twelve miles across in its widest part, i. e., from Coffeeville southwestward. It involves, so far as concerns their surface exposure, the following strata: The White Limestone, the Claiborne, the Buhrstone, and the Hatchetigbee beds, aggre-

gating, with the exclusion of the White Limestone, about 500 feet of strata. It appears to have exerted no influence upon the direction of the drainage.

In the following routes we obtain the data from which we have outlined this fold:

First. From Jackson to Coffeeville and thence northward to Wood's Bluff. On this road, 6 miles north of Jackson, the first well defined outcrop of Tertiary rocks is encountered. These rocks belong to the Buhrstone, but before reaching them the presence of the Claiborne beds at no great depth below the surface is very clearly revealed in the frequent occurrence of patches of the characteristic red, limy clays produced by the action of these beds upon the red loam. Beyond this the sands and clays of the underlying Hatchetigbee group are seen along the slope leading down to the crossing of Jackson's Creek. By turning eastward from this place the Claiborne sands, with their characteristic fossils, can be seen on Stave Creek, in Secs. 8 and 9 of T. 7 N., R. 2 E. This I take to be the southeastern limit of the anticline, for looking eastward and southeastward from this place we see nothing but the characteristic landscape of the Lime Hills region. Proceeding northward, the Buhrstone rocks are again encountered about eight miles from Coffeeville, and they extend thence to within five miles of that place. The limit of the anticline in another place, southeast of Coffeeville, is ascertained by going northeastward from Salitpa post office, which is on the Hatchetigbee formation in Sec. 31, T. 8 N., R. 1 E., towards Dead Level, in Clarke County. In this direction the Buhrstone is crossed between three and five miles from Salitpa post office. Coffeeville itself is upon the Claiborne, and going northward we pass first into the White Limestone, and at Turkey Creek, near the northern limit of T. 10 N., R. 2 W., into the Buhrstone, the Claiborne as usual making very little show upon the surface, except in the red, limy clays above noticed. The Buhrstone ridge just alluded to becomes very prominent at White Bluff, and from that place an uninterrupted view may be had of all the underlying strata down to the Wood's Bluff group. In this route, therefore, we pass over the anticline between Jackson and Coffeeville and over a syncline, with White Limestone as the uppermost formation, between Coffeeville and White Bluff, while by diverging eastward in two or three places the eastern limits of the anticline can be pretty accurately determined.

Second. On the western side of the river the anticline is equally well marked along the route from Saint Stephens, through Bladen Springs, to Butler, in Choctaw County. On this road the White Limestone may be seen to within nine miles south of Bladen Springs; then occurs a strip of pine lands, in which the underlying Claiborne formation is not often clearly seen. At one place, however, near the road in the northeast corner of Sec. 29 (corresponding to Sec. 27 in the ordinary

townships)[1] T. 8 N., R. 2 W., about a quarter of a mile west of the Tony Rail place, in the bluff over a spring, about six feet of the Claiborne sands are exposed. The upper part of this exposure is a mass of shells packed in a yellowish red sand, as at Claiborne; the lower part at the water level is a hard, greensand filled with shells, as at Pugh's Branch, in Clarke County. *Crassatella protexta* is here the commonest shell; but *Melongena alveata*, *Monoceros armigerus*, *Ancillaria subglobosa*, *A. scamba*, *A. staminea*, and other Claiborne forms are also abundant. This locality is about a quarter of a mile north of the last Lime Hill. Beyond this, towards Bladen Springs, the Buhrstone rocks are first seen at the bridge across Sinta Bogue in the northwest corner of Sec. 14, T. 8 N., R. 2 W., six miles from the springs, and they continue up to within two miles. About the central part of this outcrop, four miles from the springs, there is a marl bed several feet in thickness, containing great numbers of a shell closely allied to *Ostrea sellæformis*. This marl is found just below a hard ledge of claystone, and in the fields near by lie many fragments of rock filled with silicified Claiborne shells. The springs are upon the upper Hatchetigbee beds, for going northwards the Buhrstone is again met in the hills about two miles north of the springs, and outcrops along this road for about four miles. Beyond this Buhrstone belt we come upon the Claiborne sands on the hill just south of Souilpa Creek, and going down the hill we see the *Ostrea sellæformis* beds, and in the immediate bank of the creek the bed of comminuted shells in a matrix of greensand, precisely like that in the lower part of the Claiborne bluff and at Coffeeville landing. At Barryton Mill, about the northeast quarter of Sec. 13, T. 10 N., R. 3 W., about a mile east of the road we are now describing, this bed of comminuted shells, with numbers of large and perfect shells of *Ostrea sellæformis*, forms the bed and banks of the creek. To the westward also of this road the banks and channel of Oaktuppah Creek are formed of the lower Claiborne beds, which outcrop again on the hills some four miles north of the creek. The belt of Claiborne beds is crossed on this road from the southern banks of Souilpa Creek northward about seven or eight miles. This great width of outcrop is due to the fact that the beds form a shallow synclinal basin. This basin holds a narrow belt of White Limestone, which may be traced from Womack Hill, SE. ¼, Sec. 4, T. 10 N., R. 2 W., northwestward to the Mississippi line at Nicholson's Store. The outcrop of White Limestone at Womack Hill is about two miles long and one hundred or two hundred yards wide. Then northwestward in Mrs. Nix's field, Sec. 2, T. 10 N., R. 3 W., is another outcrop, about a mile long and two hundred yards wide. Still farther northwestward the White Limestone is next seen on the south side of Oaktuppah Creek, on Dr. Gilbert's old place and between that place and Mr. Troup Trice's. Then on the north side of Oaktuppah Creek, on Messrs. Seaborn Bonner's and Rigby's lands, Secs. 22, 23, 26, and 27,

[1] In this township the sections are numbered differently from the usual manner.

T. 10 N., R. 4 W., is a narrow tract, about two miles in width north and south; again, still farther westward, on Mr. James Bonner's land, N. W. ¼ of Sec. 15, T. 11 N., R. 4 W., is about a square mile of the White Limestone prairie. Beyond this the prairie belt widens out and merges into the great mass of prairies west of the end of the Hatchetigbee anticline. Returning to our Bladen Springs and Butler road, after crossing the syncline of Claiborne beds which holds the narrow belt of White Limestone, we come upon the Buhrstone rocks again some ten miles south of Butler, and these make the country to within five miles of that place, where they are succeeded by the Hatchetigbee beds, and at Butler by the Wood's Bluff beds.

Third. Along another route, approximately parallel to the two preceding, but in the western part of Choctaw County, we discover that our anticline has sunk beneath the surface, though still impressing itself upon the country by keeping the White Limestone as the surface rock over a distance north and south of more than twenty miles. A very similar state of things may be seen beyond the southeastern end of this fold in Clarke County, as below noted. The following details will serve to make this clear: Three miles south of Pushmataha the Wood's Bluff marl is seen on Rabbit Creek, and a mile or two farther south the first of the Buhrstone, which rock then makes the country southwestward as far as the SE. ¼ of Sec. 25, T. 12 N., R. 5 W., near Mr. Johnson Allen's. In this vicinity *Ostrea sellæformis* beds are found upon many of the high hills which show Buhrstone rocks at their bases. The line between the two formations may therefore be drawn here. Going still southward we find the *Ostrea sellæformis* or Claiborne beds at lower and lower levels, till on Billy's Creek, in Sec. 7, T. 11 N., R. 4 W., they are at the water level, and we get a first rate section extending nearly up to the White Limestone.

Section on Billy's Creek, Choctaw County.

1. Red, white, and yellow, laminated sands, with yellow clay partings.......15 feet
2. Laminated, gray clays, with bits of leaves and indistinct leaf impressions. 12 to 15 feet
3. Greenish yellow, calcareous, glauconitic sands; no fossils ....8 feet.
4. White, calcareous sands, with *Ostrea sellæformis*.......................6 feet.
5. Hard, white ledge, with shell casts.......................................1 foot.
6. White, calcareous sands, with *Ostrea sellæformis*, passing below into coarse, yellow sands, and then to gray, calcareous sands, holding a few friable shells; hard ledges traverse these beds near the top; in all.........................12 feet.
7. Highly fossiliferous, gray, calcareous sands, holding *Ostrea sellæformis* (small shells), *Osteodes Watsoni*, *Turbinolia Maclurei*, *Nucula magnifica*, *Pecten Lyelli*, &c. These are alternating streaks of barren sands and fossiliferous sands...........20 feet.
8. Gray, laminated clays to base of bluff......................................10 feet.

One of the beds of No. 7 is densely packed with the small form of *Ostrea sellæformis (divaricata)*, and this is the bed which crops out so frequently upon the hills to the northward of this locality. A comparison of the elevations of this bed in different places shows that it dips about 50 feet to the mile. South of Billy's Creek we enter upon the

wide belt of prairie land (White Limestone) which extends to the northwestern corner of Washington County four or five miles below Isney. The line between Ranges 4 and 5 W. marks about the western limit of the Hatchetigbee anticline, for east of Push Cush Creek, about Sec. 17 or Sec. 18, T. 10 N., R. 4 W., the outcrops of the *Ostrea sellæformis* beds are seen.

The map will show that in the western part of Washington and Choctaw Counties and in adjoining parts of Mississippi the width (north and south) of the White Limestone belt is much greater than elsewhere, except in the eastern part of Clarke County. This is undoubtedly in great measure due to the influence of our Hatchetigbee fold; but there is also a very considerable increase in the thickness of the beds constituting the lower or Jackson division of the White Limestone in the western part of Alabama and in Mississippi, or perhaps it would be more correct to say that there is a very considerable increase in the thickness of the beds of gypseous clay of the formation in these localities. The "prairie" character of the soils of this formation is much more pronounced in Western Alabama and in Mississippi than elsewhere eastward.

Fourth. The limits of the anticline are also well defined along several roads leading out from Bladen Springs.

(*a*) On the road from Bladen Springs to Millry, in Washington County, the Buhrstone and Claiborne formations are crossed, and at a distance of seven or eight miles from the springs appears the first outcrop of White Limestone.

(*b*) On the lower road from the springs to Isney the first outcrop of Buhrstone is about one and a half miles and the last about five miles from the springs. A very conspicuous bed in these Buhrstone rocks is a greensand, several feet in thickness, of very bright, light green color, to be seen on almost every hillside from three to four and a half miles from the springs. In many places the upper part of this bed has been oxidized to deep red sand. From the five mile post west of the springs out to the lower line of Sec. 15, T. 9 N., R. 4 W., we cross diagonally the outcrop of the Claiborne beds, coming into White Limestone at the last named locality, where along a hillside Claiborne beds are seen, with White Limestone overlying them. Thence out to Isney (and beyond to Mississippi) the country is made by the White Limestone. A very good section of the Upper Claiborne beds was obtained in Sec. 13, T. 9 N., R. 4 W.

Section near Jordan's Mill.

1. Yellowish, clayey sands, with some Claiborne fossils in a soft, friable condition; lower part of this bed bluish .... 25–30 feet
2. Projecting ledge of coarse grained greensand, with a large number of badly preserved Claiborne fossils .... 4 feet.
3. Coarse grained greensand, with Claiborne fossils, compact and hard ...... 10 feet.

The upper half of No. 3 is coarser in grain and more fossiliferous than the lower, but the latter contains a number of the smaller forms. A

little northwest of this, in Sec. 2, T. 9 N., R. 4 W., at Shoemaker's Mill, this greensand bed is again seen, holding *Crassatella alta*. While in some respects these two outcrops resemble the Claiborne sands (main fossiliferous bed at Claiborne), there are differences observed which lead us to think that their position is below these sands. The limit between Claiborne and White Limestone is seen again about half a mile northeast of Fail's Store.

(*c*) Along the upper road from Isney to Bladen Springs the Buhrstone belt is entered at Powe's Store, about two miles northeast of Silas post office, and from this point on by the Turkey Creek bridge (about Sec. 10, T. 9 N., R. 2 W.) we cross only Buhrstone rocks. No Hatchetigbee beds are observed. From this circumstance it would seem that the outcrop of the last named beds, passing through Bladen Springs, does not extend northwest beyond the line running from Silas to Turkey Creek bridge, these two points being on opposite slopes of the anticline. In the piny woods northeast of Isney there are many outcrops of the *Ostrea sellæformis* beds, betrayed by the appearance of red, limy clay spots in the woods. Thus at Singeley & Peel's store, Sec. 11, T. 10 N., R. 5 W., the immediate surface is sandy and timbered with long leaf pine, but prairie spots (White Limestone) occur on the hillsides in all directions. Two and a half miles due east of this store, in the banks of Push Cush Creek, the *Ostrea sellæformis* beds are seen, as also at Mr. Marion Carroll's (Sec. 21, T. 10 N., R. 4 W.), and in the piny woods southeastward, eastward, and northeastward, for a good many miles.

(*d*) Again, going towards Bladen Landing, Sec. 3, T. 9 N., R. 2 W., the road is over Buhrstone all the way, after leaving the immediate vicinity of the springs.

(*e*) And lastly, going from the springs to Coffeeville, after leaving the Hatchetigbee clays of the springs, the road passes over Buhrstone to the river lowlands; it then follows the river for three miles (no rocks seen) to Coffeeville, where the Claiborne rocks are well exposed. At Coffeeville Landing these rocks have a very strong dip towards the east or northeast, and the White Limestone is encountered within a very short distance of the river bluff eastward. Thus, on the road from Coffeeville to Grove Hill, we see orbitoidal limestone at the level of the small water courses, within five miles of the former place, and at six miles from Coffeeville this rock forms the banks of Satilpa Creek. This marks about the lowest part of the depression, for a mile farther eastward limy clays containing ribs of Zeuglodon are noticed upon a hillside, at some considerable elevation above the level of Satilpa Creek. These lime hills continue thence to within a mile of Grove Hill, where the Tertiary rocks are concealed by the Drift deposits.

From these details it will be seen that this anticline has been tolerably well defined on all sides by our observations, and its representatives on the other map may be taken as fairly correct. In describing the

limits of this undulation we have made use of the Buhrstone rocks more than of other formations, for the reason that the Buhrstone, being in general hard and resistant to denudation, may almost always be seen along its line of outcrop. The Claiborne beds (sands and clays), on the other hand, as a rule, are likely to escape detection. It may, however, be of interest to give the following localities of the occurrence of the Claiborne along the two sides of the anticline.

The ferruginous sand bed, with the great mass of the Claiborne shells, we have seen less frequently than the lower or *Ostrea sellæformis* beds.

The former has been observed on the southern side of the anticlinal on Stave Creek, in the SW. ¼ of Sec. 8 and in the SE. ¼ of Sec. 9, T. 7 N., R. 2 E., in Clarke County; on the Tombigbee River, half a mile above Saint Stephens Bluff; also in Sec. 5, T. 8 N., R. 2 W., and in Sec. 29, T. 8 N., R. 2 W., in Washington County. Then in Sec. 13, T. 9 N., R. 4 W., and in Sec. 2, T. 9 N., R. 4 W. On the northern side of the anticline the ferruginous sand bed has not come under observation except on the southern bank of Souilpa Creek, about Sec. 13 or Sec. 25, T. 10 N., R. 3 W.

On the other hand, the lower or *Ostrea sellæformis* beds are to be seen along the whole outline of the anticlinal, and even where the beds do not come to actual outcrop their presence is just as certainly revealed by the occurrence of what are called "piny woods prairies"—that is, red, limy, clay spots in the piny woods. A great proportion of the country underlaid by the *Ostrea sellæformis* beds has a light, sandy soil and is timbered with long leaf pine, and the reaction of the calcareous sands upon the red loams, which occur in these sandy lands, produces the so-called prairie spots. I give a few of the localities of *Ostrea sellæformis* beds around the anticline, beginning at Coffeeville Landing, where there is a fine exposure. Thence northwestward they may be followed up Oaktuppah Creek, on both sides, and forming the bed of the creek in many places, out towards Nicholson's store. Thus, on both sides of Womack Hill, at Barryton Mill; on Surveyor's Creek, Sec. 36, T. 11 N., R. 3 W.; in the banks of Souilpa Creek, at the bridge, about Sec. 13 or Sec. 25, T. 10 N., R. 3 W.; two miles west of Barryton; in the bed of Oaktuppah Creek, about Sec. 28, T. 11 N., R. 3 W.; in Sec. 20, T. 11 N., R. 3 W., on Bogue Loosa; in many places northward as far as Lusk post office, SW. corner of Sec. 9, T. 11 N., R. 3 W.; in Sec. 25, T. 12 N., R. 5 W.; Secs. 6 and 7, T. 11 N., R. 4 W.; in Sec. 15, T. 11 N., R. 4 W.; many places near center and northern part of T. 10 N., R. 4 W.; and thence along the southern border of the anticline, i. e., about Sec. 7 or Sec. 8, T. 8 N., R. 2 W.; then across the river a few miles north of Jackson, &c. Indeed, with a little practice, the *Ostrea sellæformis* beds are about as easily followed as the Buhrstone. In Clarke County, also, as across the river in Choctaw County, in the syncline lying to the northeast of the Hatchetigbee anticlinal, the Claiborne ferruginous sands are in many places not far below the general level of the country,

and are exposed in the beds of the water courses. Examples of this are seen in the central part of Sec. 23, T. 9 N., R. 2 E., and in the SE. ¼ of Sec. 18, T. 9 N., R. 3 E.

It will be noticed that along the sides of this anticline, as well as where the Buhrstone first dips below the surface in the northern part of Clarke and Choctaw Counties, the rate of dip is much greater than the average of 30 feet to the mile; for the thickness of the Buhrstone is about three hundred feet, and its outcrop, with a dip of the strata of thirty feet to the mile, would be about ten miles broad, but in the instances cited above this outcrop will not average more than four miles in width. A part of this difference is undoubtedly due to the fact that the Buhrstone usually forms high hills, with a rather steep escarpment looking northward, but a part is also certainly due to the more rapid dip along these lines.

(3) OTHER BUHRSTONE DISPLACEMENTS.

A few words respecting the appearance of the Buhrstone rocks at localities farther south than the anticline just described may not be out of place here. A few miles south of Jackson, on the road to Gainestown, there is a hill which rises to a height of 300 feet above the adjacent water courses. Upon its summit there is a good outcrop of Buhrstone rocks, and in immediate contiguity with it Orbitoidal White Limestone, at the same level. This state of things may be seen also southward and northward of the locality named for at least a mile in each direction, and southward presumably as far as the Lower Salt Works (see below). The locality mentioned is about the corner of the four sections 14, 15, 22, 23, T. 6 N., R. 2 E.; and a mile north of it, in the Etheridge Old Fields, there is another occurrence of Buhrstone and White Limestone in actual contact apparently at the same level, for in both these cases, as we go eastward, we find the White Limestone making the country for many miles. In the same range of hills with the outcrops above mentioned (but eastward of the Buhrstone occurrences), there are places where the ravines have cut down into the *Ostrea sellæformis* beds of the Claiborne. The Tertiary strata lying westward of these localities have generally been removed by denudation, but in one place at least, we find Orbitoidal White Limestone lying to the *west* of the line of contact of Buhrstone and White Limestone, so that to all appearances we have here a narrow belt of Buhrstone (north and south) coming up right in the midst of the White Limestone, and with the latter in visible contact with it on its eastern side. When we go a few miles farther south, to what is called the Central Salt Works, in the northern part of Sec. 34 or the southern part of Sec. 27, T. 6 N., R. 2 E., we find the Orbitoidal White Limestone at the level of the water courses, but a mile east of the Salt Works, up Salt Creek, on ascending a hill we pass over what appear to be the Hatchetigbee strata. Of this I could not be perfectly sure, as no well defined fossils were obtained; but on

another branch of the creek, which flows from the north, heading nearly in the localities first mentioned, we find the Buhrstone making the lowermost forty or fifty feet of the hills in both sides of the branch, while the upper strata of the hills were White Limestone, apparently *conformably overlying the Buhrstone*, the strata of the latter at one place, where they were clearly shown in a low bluff, being approximately horizontal. This locality is near the upper edge of Sec. 35 or of Sec. 36 in T. 6 N., R. 2 E., or in the lower part of the section lying next towards the north. At Mr. F. Payne's spring, on the NW. ¼ of NE. ¼ of Sec. 11, T. 5 N., R. 2 E., the Buhrstone is found, while directly west, on the bank of the river, in Secs. 16, 17, 21, 28, and 29 the White Limestone appears. So, also, east of Mr. Payne's house there are lime sinks and outcrops of White Limestone in Secs. 12, 13, 24, &c. Though not actually seen, it would appear that here, also, we have the White Limestone lying directly upon the Buhrstone, the strata falling away rapidly westward so as to bring the former rock down to the river within two or three miles towards the west. A few miles below this, in Secs. 21 and 28, T. 5 N., R. 2 E., at the Lower Salt Works, we have the section already given, in which the White Limestone and the Buhrstone are shown in direct contact, the former apparently directly and conformably overlying the latter, just as appears to be the case at Mr. Payne's, at the Central Salt Works, and probably also at the first locality mentioned above (Secs. 14 and 15, T. 6 N., R. 2 E.).

I should be inclined to explain these anomalies on the supposition that a north and south fault has brought the Buhrstone and the White Limestone together, but for the fact that at most of the localities above mentioned the White Limestone may be seen directly, and to all appearance conformably, resting upon the Buhrstone. Whether by a fault or otherwise, all the Claiborne strata are wanting at all these localities, and my observations show also either that there is an anticlinal axis extending from Sec. 28 in T. 5 N., R. 2 E., a little east of north up to Sec. 14, T. 6 N., R. 2 E., which brings the Buhrstone above drainage along this line and for this distance, or that this elevation has been brought about by a fault. There are great difficulties in the way of making satisfactory observations in this part of the State, as thick beds of drift and loam (in some places, as at Mr. Payne's, 75 feet thick) cover the whole face of the country, except where they have been removed by the few streams; but I hope to have this fold or fault fully traced out in another season.

The sulphur spring at Jackson comes apparently through the Buhrstone out of the Hatchetigbee strata, as is the case at Bladen Springs, Tallahatta Springs, the Upper Salt Works, the Lower Salt Works, &c. The Jackson well, however, is in the low grounds of Bassett's Creek, and no Tertiary rocks show in the immediate vicinity, but the Buhrstone and the Hatchetigbee sands appear on a hill at no great distance towards the east.

As before stated, the White Limestone is the country rock through all the lower part of Clarke County, as far south at least as Choctaw Bluff and the Lower Salt Works; but away from the streams these Tertiary beds are hidden by drift, and their presence is revealed only by the numerous lime sinks which are of such frequent occurrence in the piny woods of this section. Below the Lower Salt Works the Tertiary rocks may be continuously followed down to Oven Bluff, a few miles distant, southward of which point they do not appear to come again to the surface. It is probable, however, from the occurrence of lime sinks, that the White Limestone underlies the surface at no great depth for many miles farther in this direction.

The uplift of the Lower Salt Works is felt across to the Alabama River, but not to the same degree as here, for at Gainestown and at Choctaw Bluff the lower measures of the White Limestone are at the water level.

It would not be correct to say that these undulations are not felt at all across the whole of Clarke County; for, although the underlying Claiborne and Buhrstone rocks are not, so far as we now know, lifted much above the general drainage level in the eastern part of the county after having once disappeared beneath the surface, the undulations have still been operative in keeping the White Limestone as the surface rock over an extent, north and south, of 30 miles. This is well illustrated along the meridian of Grove Hill, Clarke County, where we find the White Limestone as surface rock from about five miles north of that town down to Choctaw Bluff, and the thickness of the formation is not much over 300 feet. Moreover, at several localities we find the underlying Claiborne beds at no great depth below the general level of the country. Now, if we travel southward of this last outcrop of the White Limestone at Choctaw Bluff, through Monroe and Escambia Counties, and eastward also, in Covington, Coffee, and Geneva Counties, we find the country generally level piny woods, with a surface mantle of drift, in which, however, the frequent occurrence of depressions caused by lime sinks reveals the fact that the White Limestone is at no great distance from the surface at any place. And, still further, if we pass into Florida we find this rock again at the surface over the greater part of the peninsula, although, as recent discoveries of Mr. L. C. Johnson have shown, covered in many places by later deposits of Miocene age.

The elevation of the Florida peninsula was therefore subsequent to the deposition of the Miocene beds, and the undulations of the Alabama Tertiary may date back to the same epoch. That these disturbances antedate the elevation of the Terrace epoch is shown by the circumstance that the Drift (Champlain) deposits rest upon an eroded surface of the Tertiary (Eocene and Miocene) rocks.

(4) EASTERN EXTENSION OF THE BUHRSTONE.

By referring to the map it will be seen that the northern line of the Buhrstone outcrop, after crossing the Alabama River just below

Johnson's wood yard, turns sharply northeastward to a point nearly east of Bell's Landing and six or seven miles distant therefrom. Then it turns southward six miles, sweeps around eastward and northeastward just south of the lower prong of Flat Creek, running up as far north as Cokerville, near the line between Monroe and Conecuh Counties. Beyond Cokerville it again makes an abrupt turn southeastward and crosses the extreme southwestern corner of Butler County, beyond which point it has not been continuously followed. The two extreme northern points above noted, namely, that east of Bell's Landing and that at Cokerville, are upon dividing ridges, and this northward extension is no doubt in part due to this circumstance, but not altogether. The course of the two branches of Flat Creek has also much to do with this peculiar surface distribution of the strata. These two branches rise near Cokerville, in the northeastern part of Monroe County. The southern branch flows southward and westward, its channel being mostly in the Wood's Bluff strata, while the Hatchetigbee and Buhrstone form an escarpment on the southern border of the creek valley down to its confluence with the northern branch. The latter flows at first northward, then westward, and then southward to the point of confluence above noted. It thus flows out of the Wood's Bluff strata into the Bell's Landing, and even into the Nanafalia beds, coming back in its southward course into Wood's Bluff again, six or eight miles above the confluence.

Northward of the upper branch of Flat Creek we have a wide area of outcrop of the Nanafalia beds in the Grampian Hills of Wilcox County, in some places eight or ten miles in width.

Our observations have not given us the complete explanation of any of these irregularities, and this mere notice of them must suffice for the present.

CRETACEOUS STRATA.

The Rotten Limestone division of the Cretaceous in Alabama consists of about one thousand feet of calcareous strata of very great uniformity in lithologic character throughout, and, similarly, the strata of the Eutaw division are cross bedded sands and laminated clays, possessing no very well marked features in any part; and the same is true of the beds of the Tuscaloosa formation. While, therefore, we might expect to find disturbances in the strata of the Cretaceous group, such disturbances are not easily recognized in the two great subdivisions of this group, by reason of the uniformity in lithological composition above noted. In the upper or Ripley formation of the Cretaceous, on the other hand, alternations of sandy strata with calcareous and fossiliferous strata are easily identified, and disturbances in the stratification do not so easily escape detection.

While our observations in the Cretaceous territory have not been so extended as in the Tertiary, we are yet able to note a few instances of well marked irregularities in the Ripley formation of this group.

(1) CANTON LANDING, ALABAMA RIVER.

In the river bluff at this locality we have the following section of the Ripley strata:

Section at Canton Landing, Alabama River.

1. Surface beds covering first terrace of the river.....................undetermined.
2. Light gray, calcareous sands, with an indurated ledge of nearly pure sandstone at base ....6 feet.
3. Bluish gray, sandy clays, passing downwards gradually into a more sandy bed containing numerous phosphatic casts and nodules (sandy bed 3 feet thick) ..6 feet.
4. Bluish, argillaceous, calcareous beds, holding great numbers of *Exogyra costata*, *Gryphæa*, and casts...3 feet.
5. Bluish, calcareous sands containing many fossils, chief among which a *Spondylus*, a *Nautilus*, and turreted shells, to water level ....3 feet.

In one place here a block about 50 yards long of the face of the bluff has been broken from the rest of the strata and settled down some six to eight feet, bringing the base of bed No. 2 of the section down to the top of No. 4 of the undisturbed strata.

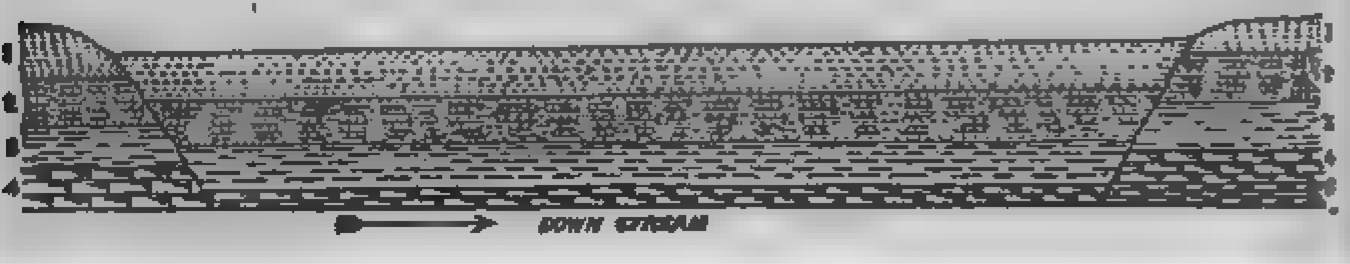


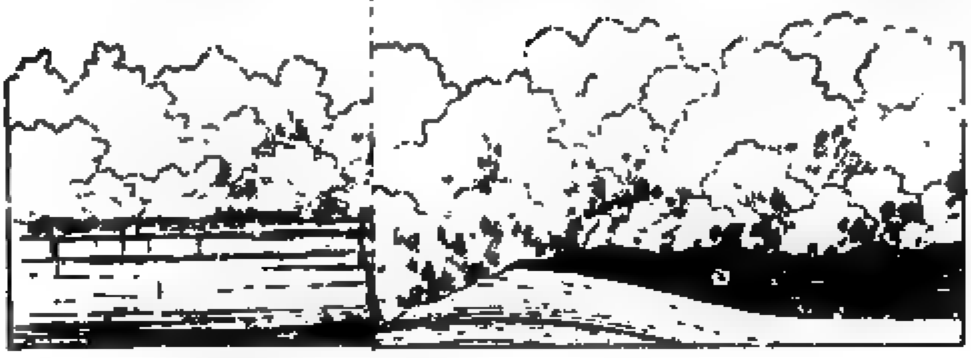
Fig. 1. Displacement at Canton Landing.

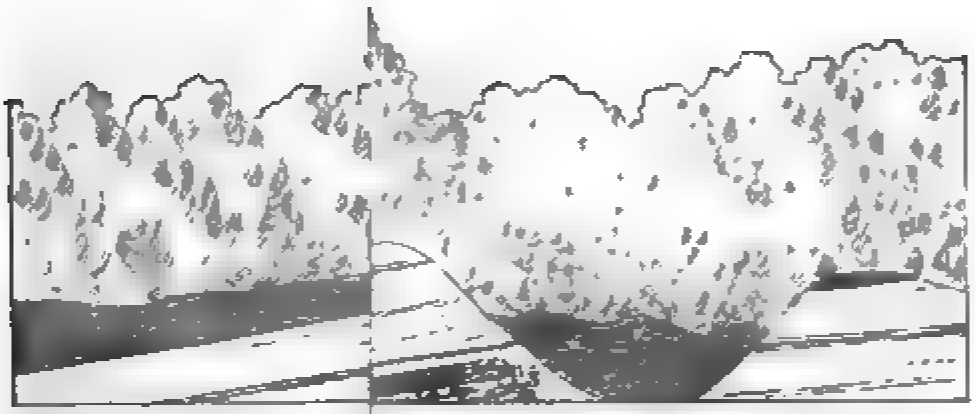
The figure gives an idea of this, and it is to be remarked further that the beds of the main bluff at the left of the break are lower than those at the right (with reference to the water level) by two or three feet.

(2) PRAIRIE BLUFF, ALABAMA RIVER.

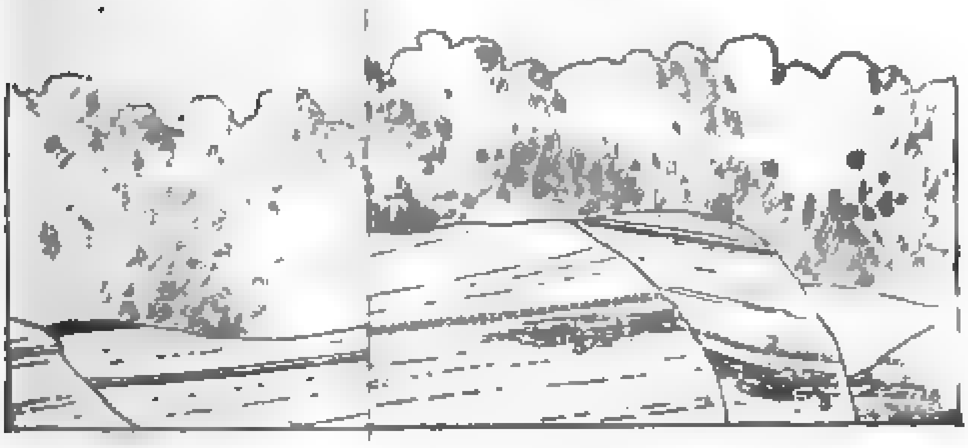
At this place, as noted above, we have at the top of the bluff some 15 or 20 feet of fossiliferous, calcareous beds, including part at least of those just given as occurring at Canton Landing, and below these to the river level some 60 feet of sandy strata traversed by bands of indurated sands containing numbers of large shells of Gryphæa and Exogyra. These sandy strata have a very rapid dip down stream (southward) of some 300 to 350 feet to the mile; while the calcareous beds at the top of the bluff, according to the recent observations of Mr. Langdon, show a much less decided dip, it being only about 30 or 40 feet to the mile. This may be and probably is due to the cross bedding on a large scale of the sandy strata.

A mile or two above Prairie Bluff we have another exposure of these sandy strata, with similar rapid dip down stream. This dip, if uniformly continued down to Prairie Bluff, would bring these beds 300 to 400 feet below the visible portion of that bluff, while in all probability





(Black, shaly clays, No. 1 cross-bedded sandstone embedded in the lim...



2. Thin ledge of Gryphæa shaults are shown in this part of the river bank.)

...tion on page 79.

DIAGRAM SH...SE DOWN THE RIVER.

the strata of the two bluffs are, in part at least, the same, and it is probable that between the two places these strata undulate very decidedly or are perhaps faulted.

(3) MOSCOW, TOMBIGBEE RIVER.

Some of the calcareous beds of the Ripley formation are exposed along the right bank of the river from Moscow a mile or two down stream. In these bluffs, which are continuous, about fifty feet in all of these strata may be seen, and there is no difficulty in following any particular stratum to its disappearance below the water level. The strata here exposed are the following:

Section near Moscow, Tombigbee River.

1. Black, shaly clay like that of Black Bluff, supposed to be Tertiary, but devoid of fossils .... 10 to 15 feet.
2. Dark blue, argillaceous limestone, with thin, projecting ledges of harder material. One of these ledges, about 8 feet below the black clay, is very persistent, and easily followed from Moscow down to the cut off just above the mouth of Sucarnochee Creek .... 20 to 30 feet.
3. Thin ledge of shells of a small *Gryphæa* .... 1 to 1¼ feet.
4. Hard, argillaceous, white limestone, resembling the Rotten Limestone, containing many Cretaceous shells, as *Exogyra costata, Gryphæa mutabilis*, &c., especially in the upper part, which is indurated .... 25 feet.

Near the top of stratum No. 4 there are at several places along the river hard, sandy ledges of very irregular shape, and discontinuous. These sandstones contain comminuted shells embedded in a sandy matrix. The thin ledge of Gryphæa shells (No. 3) and an indurated ledge near the top of No. 2 are easily recognized, and they serve to identify the other beds.

In going from Moscow down to the cut off we see that the above described strata are not only undulating but at seven or eight places distinctly faulted.

The accompanying diagram of the right bank of the river, carefully sketched from nature, shows very clearly the character of these disturbances and renders any further description in words superfluous (Plate X).

VI. RÉSUMÉ.

THE FORMATIONS.

The general section forming Plate XXI is so arranged as to exhibit in the two inner columns, by conventions and descriptive text, the structure and character of the formations exposed along the rivers traversed and our conceptions of their relations. The portions of the sections in which the conventions are introduced are constructed from observations recorded in the foregoing pages and the portions left blank represent those parts of our ideal section in which exposures do not occur along either river. In the two outer columns are exhibited in similar

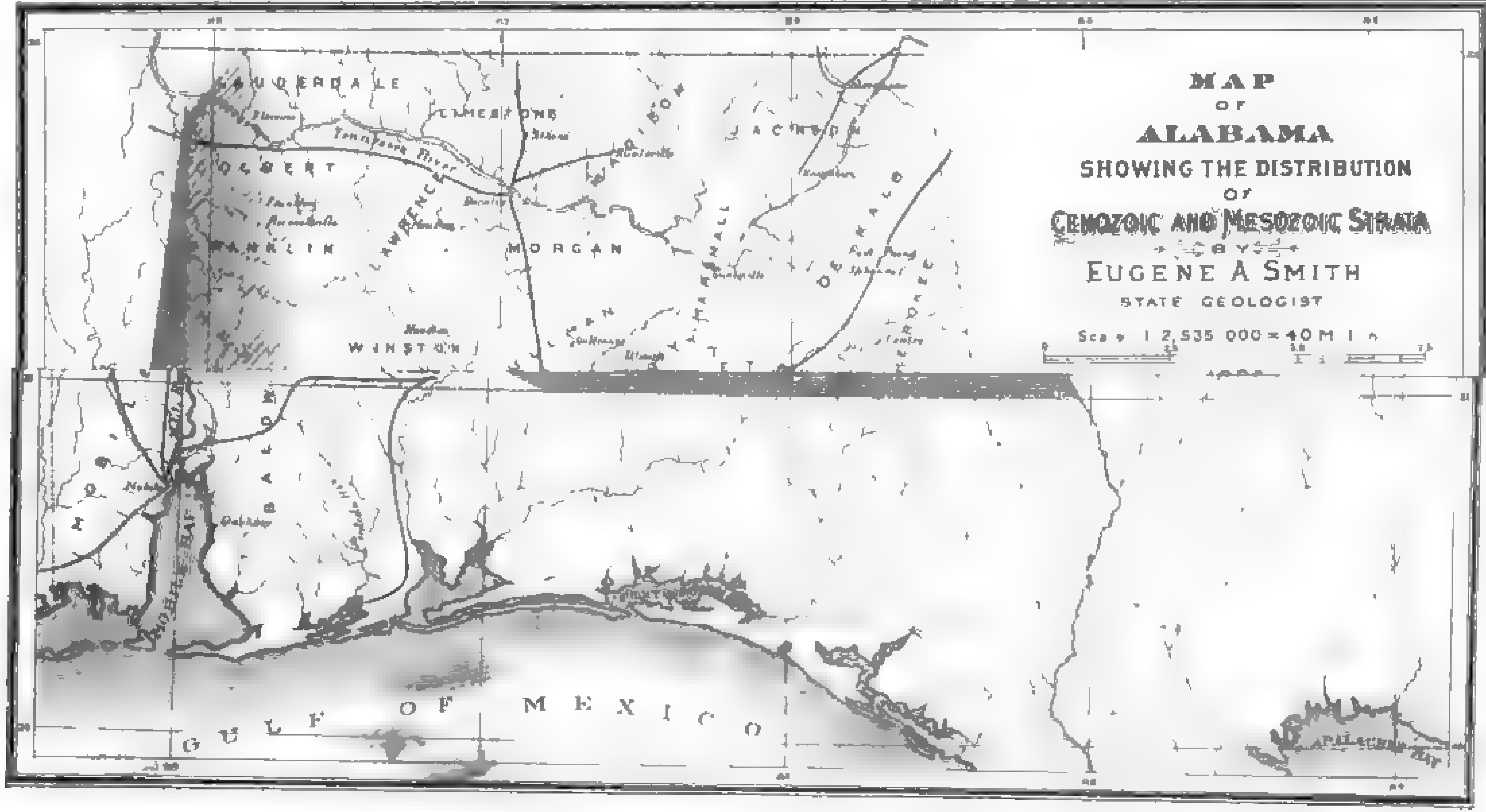
manner those portions of the formations not actually seen along either river, which are either exposed in the immediate vicinity of the rivers so clearly as to leave no doubt as to their stratigraphic relations or else disclosed by artesian borings. These two columns, therefore, serve either to fill out the missing parts of the river sections or to confirm the measurements made elsewhere.

By reference to the text and to the general section it will be seen that in the Tertiary group we have been able to fill up the blanks thus occurring along the rivers by direct measurement of the exposures seen in the vicinity of the rivers, except in two places, viz, just below the Bell's Landing section and below the Coal Bluff section of the Lignitic. The stratigraphic column of the Tertiary formation, therefore, with the two exceptions noted, is constructed from actual measurements. From the known thickness of the several divisions which we have made in the Tertiary and their extent upon the surface, we find, from careful observations made at many points, that the average general dip of the Tertiary strata is about 30 feet to the mile towards the southwest. There are, however, undulations and variations in the dip, culminating in the vicinity of the Tombigbee River, where the disturbances are more conspicuous than anywhere else in the post-Appalachian clastics of the Atlantic and Gulf slopes, so far as known. These have been described in the preceding pages.

Similarly in the upper part of the Cretaceous group the stratigraphic column has been constructed in great part from actual measurements; but in the lower part of the known Cretaceous and in the whole of the Tuscaloosa formation, where our observations have been less numerous and satisfactory, we have assumed a uniform southwesterly dip of 40 feet to the mile, and the thicknesses thus assigned to the imperfectly exposed beds are only approximations, though, as we think, close approximations. In the artesian boring at Livingston, which is upon the extreme southern border of the Rotten Limestone, the thickness of this rock actually penetrated is 930 feet, and as the Rotten Limestone forms the surface between Livingston and Eutaw, a distance across the strike of 24 miles, the average dip is seen to be about 40 feet to the mile.

Some of the leading structural features of the formations described may be recapitulated.

The newest of the formations exposed along our route is the White Limestone. It consists chiefly of regularly bedded, impure limestone, with intercalated layers of marl, calcareous clay and sand, and some ledges of pure limestone. Its upper portion is perceptibly more calcareous than the lower and contains a notably greater proportion of deep sea fossils; but neither the lithologic nor the paleontologic features are sufficiently distinct to warrant division of the formation. Its position and its structure alike indicate that it was laid down in a deep and probably deepening sea.


MAP
OF
ALABAMA
SHOWING THE DISTRIBUTION
OF
CENOZOIC AND MESOZOIC STRATA
BY
EUGENE A SMITH
STATE GEOLOGIST
Scale 1:2,535,000 = 40 M. 1 in.
LAUDERDALE
LIMESTONE
MADISON
JACKSON
COLBERT
FRANKLIN
LAWRENCE
MORGAN
MARSHALL
DE KALB
CHEROKEE
WINSTON
BALDWIN
MOBILE
Tennessee River
MOBILE BAY
GULF OF MEXICO
APALACHEE BAY

The Claiborne formation is made up of tolerably uniformly bedded, calcareous, and generally glauconitic sands and clays, containing rather shallow water, but not littoral, fossils mingled with deep sea organisms. There is no conformity or clearly marked line of demarkation between the Jackson beds of the White Limestone and the upper calcareous beds of the Claiborne, the one grading imperceptibly into the other, both lithologically and paleontologically.

The Buhrstone deposits are sands and clays variously interstratified, generally lithified by silicious cement. Some of the clays are remarkably pure and fine grained. The fauna is meager, but of facies identical with that of the Claiborne.

The Lignitic formation comprises three well marked divisions defined by color, which is here an index of constitution. The upper one-fourth consists of irregularly bedded, dark, silicious, and lignitiferous clays and heterogeneous sands, approaching the basal portion of the Buhrstone formation in composition and structure, interstratified with discontinuous beds of lignite and continuous layers of clay and sand containing marine fossils. The medial three-fifths of the formation is made up of rather more regularly stratified clays and sands of light color, frequently cross bedded, containing occasional beds of lignite and of marine sands yielding littoral fossils, one of which (the *Gryphœa thirsæ* bed) is 50 to 60 feet in thickness. The basal deposits are irregularly bedded, dark, or even black, calcareous, shaly or slaty clays, with few fossils or definite beds of lignite, though considerable quantities of carbonaceous matter are disseminated throughout its mass.

At the base of the Lignitic there is a rapid change in the character of both rocks and fossils, the lowermost 15 or 20 feet of the formation being limestone, at first argillaceous, then quite pure, and even crystalline. This crystalline limestone rests with apparent conformity upon the yellow sands which make the summit of the Cretaceous group.

The materials of the Ripley formation are generally fine and uniformly bedded, particularly toward the summit, are predominantly arenaceous at top and bottom, though notably calcareous, particularly in the middle layers, and are often richly phosphatic. The formation is characterized by littoral or offshore, but not strictly pelagic, fossils.

The Rotten Limestone consists of uniformly bedded and tolerably homogeneous, argillaceous, or rarely pure limestones and clay marls, with occasional intercalations of clay and sand, sometimes glauconitic. Its abundant fauna is pelagic rather than littoral.

The transition beds between this and the Eutaw formation—the Tombigbee sand of Hilgard—are predominantly arenaceous and glauconitic, and speak of shallower waters than those of the Rotten Limestone.

The Eutaw deposits, like those of the Ripley, are usually fine and uniformly bedded, though they are more arenaceous than those of the latter formation. They consist of alternations of sand and clay, the former often cross bedded and glauconitic, and the latter lignitiferous,

together with occasional lignitized tree trunks and intercalated beds of lignitic matter or pebbles. The rare fossils have a littoral aspect.

No unconformity has been found between the Eutaw and Tuscaloosa formations, and the similarity in lithologic character and attitude of the two is so close that search for discordance is unpromising.

The Tuscaloosa formation consists of a great series of irregularly or obscurely bedded, quartzitic and micaceous sands, often cross stratified; heterogeneous clays, sometimes carbonaceous or lignitiferous; lenticular pebble beds (the pebbles very commonly of chert); and discontinuous lignitic layers. With the exception of the lignite and leaf impressions, it has yielded no fossils.

The coarse sands and laminated clays forming the base of the Tuscaloosa formation repose unconformably upon the eroded surface of the Carboniferous and other Paleozoic rocks.

THE GENESIS OF THE FORMATIONS.

A preliminary report on a limited region is scarcely the place for recording a chapter in the evolution of the continent; but we are convinced that, by reason of the poverty in organic remains of many of the formations, the paucity of our knowledge of the geographic distribution and local variation of their faunas and floras, and the unity and simplicity of the terrestrial oscillations to which they are referable, the Cenozoic and Mesozoic formations of the Gulf and Atlantic slopes must eventually be correlated physically rather than paleontologically; and we at the same time emphasize this conviction and contribute toward the chief end of geologic science—the co-ordination of terrestrial phenomena—by setting forth in terms of written language what we conceive to be the history recorded in the Cenozoic and Mesozoic rocks of Alabama.

At an undetermined epoch in the Mesozoic, the southern extremity of the Appalachians, together with the Piedmont region on the east and the Cumberland Plateau on the west, was submerged; and the uneven surface sculptured by subaërial erosion formed an irregular shore line diversified by a multitude of estuaries and a highly inclined and unequal sea bottom. Within the estuaries and upon the uneven sea bottom the strong currents, high tides, and violent waves of a deep sea coast washed here and there, assorted rudely, and finally deposited the coarse detritus brought down by numerous streams of high declivity—the upper reaches of river courses shortened by submergence and steepened by tilting; the strong currents, the constant shifting of the littoral deposits, and the variable salinity of the estuarine and shoreward waters (depending upon the seasonal and non-periodic variability in stage of the affluents) were inimical to organic existence; but leaves, logs, and other vegetal matters were occasionally swept into the sea by the rivers. The downward movement during this epoch was

interrupted and, about the middle of the epoch, perhaps reversed; but in general it went on progressively. With continued deposition a submarine terrace analogous to those now fringing the Atlantic and Gulf coasts was apparently developed; and, with the growth of the terrace and consequent shallowing of the offshore waters, there was evidently a diminution in strength of currents and violence of waves, accompanied by a diminution in heterogeneity and coarseness of sediments. The deposits produced by these agencies are those of the Tuscaloosa formation.

During the epoch immediately succeeding that of the deposition of the Tuscaloosa formation, so far as our present knowledge indicates, there occurred a diminution in the rate or perhaps a cessation of the downward continental movement; but there were continued growth of the submarine terrace, shoaling of the sea by reason of sedimentation, and some recession of the shore line. The shoal water deposits of this epoch constitute the Eutaw formation.

The Rotten Limestone epoch was apparently inaugurated by a comparatively sudden renewal of the continental depression and rapid deepening of the sea. The sands of the Tombigbee were distributed by the advancing waves of the encroaching sea, and in the deep waters of the succeeding episode the abundantly fossiliferous limestones and marls of the later Cretaceous were laid down. During this epoch the waves of the Cretaceous probably lapped upon the Appalachians higher and farther inland than the Tuscaloosa shore line.

The succeeding epoch was marked by a reversal in terrestrial movement, progressively increasing coarseness and heterogeneity of sediments, rapid retreat of the shore line down the gentle slope of the adolescent submarine terrace, diminution in salinity commensurate with the relatively great (though absolutely constant) influx of fresh waters, some commingling of terrestrial plant débris with the sediments, and diminution in abundance of marine organisms. The deposits of the epoch constitute the Ripley formation and indefinitely mark the closing stages of the Cretaceous period.

The Tertiary was introduced by a continuation of the Ripley elevation sufficient to produce shoaling of the ocean over the then broad submarine terrace, diminished salinity of the littoral waters and consequent destruction of marine organisms, and extension of the terrestrial flora and commingling of its remains with the littoral deposits. There is thus a paleontologic but not (in the portions of the formations that have resisted erosion) a physical break in the sequence of events and in the continuity of strata. The altitude of the land with respect to the sea was generally persistent throughout the Lignitic epoch, but depression apparently went on pari passu with sedimentation, and there were occasional oscillations and consequent incursions of the sea upon the land—notably those represented by the Wood's Bluff and *Gryphæa thirsæ* beds—and excursions of the terrestrial flora upon the coastal marshes.

The Lignitic formation is the analogue of the Tuscaloosa; but by reason of the less acclivity and the less inequality of the sea bottom and the greater regularity of the shores the waves and currents were less violent, and in consequence the deposits are more homogeneous. The approximate horizontality and the shallowness of the sea bottom are attested by the great geographic extent of beds referable to slight changes in depth of the littoral waters.

From the initiation of the Tuscaloosa epoch to the close of the Lignitic, the offshore sediments appear to have been pushed progressively farther and farther into the sea, and the depression accompanying the sedimentation appears to have been uniform throughout the area over which the deposits are now exposed; but the Lignitic epoch was apparently terminated by a depression (perhaps due to its own weight) of the margin of the subaqueous shelf thus formed, and a consequent increase in depth of the off shore waters and in violence of waves and currents. These conditions induced increased heterogeneity and coarseness of deposits, the invasion of a deep sea fauna, and the entombment of its remains in littoral deposits. The formation thus developed we denominate the Buhrstone. The shore probably retreated rapidly and far inland during the Buhrstone epoch, particularly in its earlier episodes.

The Buhrstone epoch waned with the cessation of the seaward tilting; and, with the consequent reconstruction of a submarine terrace and some concomitant depression, there was introduced a slight physical change in the character of the deposits, without paleontologic break, marking the introduction of the Claiborne. Throughout, the Claiborne epoch depression proceeded somewhat more rapidly than sedimentation, and with increasing depth of waters went increasing homogeneity and fineness of deposits.

The continuation of the Claiborne depression was accompanied by gradual modification in physical character of the deposits and by differentiation of fauna, culminating in the latter part of the White Limestone epoch, when the Tertiary sea reached a depth approaching and perhaps equaling the maximum attained during the Cretaceous.

During the Claiborne and the White Limestone epochs the distribution of sediments was apparently such as again to bring the sea bottom to approximate horizontality; and, with what appears to have been a sudden re-elevation of the land, conditions similar to those under which the Lignitic formation was laid down were once more introduced, and the shoal water strata of the Grand Gulf formation — the homologue of the Lignitic — were laid down upon the seaward margin of the White Limestone.

Thus, our preliminary observations suggest the movements and in some cases the positions of the Cenozoic and Mesozoic shore lines, and enable us to say that the breaks in stratigraphic and paleontologic continuity in these formations are apparent rather than real and are due to simple and readily determinate continental movements.

PLATES XII-XXI,

WITH EXPLANATIONS.

PLATE XII.

SECTIONS OF THE WHITE LIMESTONE ALONG THE TOMBIGBEE AND ALABAMA RIVERS, IN PART SHOWING THE RELATIVE POSITIONS OF THE WHITE LIMESTONE AND THE CLAIBORNE BEDS.

FIG. 1. *Section of Salt Mountain, Clarke County.*

1. White Limestone, forming Salt Mountain. This limestone consists in great measure of masses of partially silicified corals. In the lower strata compact, crystalline limestone occurs, which holds plates and spines of echinoderms....150 feet.
2. Orbitoidal White Limestone quarried for building purposes ....20 feet.

FIG. 2. *Saint Stephens Bluff, Tombigbee River.*

1. Soft White Limestone, with *Orbitoides Mantelli.* The upper half contains this fossil in great abundance, the lower part more sparingly. The lithological character of the whole 70 feet is quite uniform. The top of Saint Stephens Bluff is here represented as equivalent to the top of the orbitoidal limestone at Salt Mountain, giving the *minimum* thickness of this rock. There may be, however, a greater thickness of this rock than here shown ....70 feet.
2. Indurated bed of *Spondylus dumosus*..3 feet.
3. Light yellowish white marl or argillaceous limestone, containing nodules of phosphate of lime. The marl itself is strongly phosphatic ....27 feet.

FIG. 3. *Section at Baker's Hill, continuation of Saint Stephens Bluff, showing relative positions of the White Limestone and the Claiborne sands, Tombigbee River.*

1. Orbitoidal White Limestone forming summit of hill, passing into the argillaceous limestone below (line between the two here rather arbitrarily drawn)....25 feet.
2. Argillaceous, glauconitic limestone, with *Pecten perplanus, Pecten Poulsoni,* &c. This is the same rock as that at base of Saint Stephens Bluff, half a mile distant and in plain sight. The strata are covered at intervals by débris.
3. Bed with *Scutella Lyelli,* 1 foot seen; at other points.......................3 feet.
4. Coarse, ferruginous sands passing downwards to reddish sand, holding the usual Claiborne fossils of unmistakable character.........................15 to 18 feet.
5. Bluish green, glauconitic, and clayey sands, containing the *Flabellum* found at Coffeeville ....8 to 10 feet.

FIG. 4. *Strata exposed in continuous bluffs between Marshall's Landing and Rattlesnake Bluff, just below Claiborne, showing relative positions of the White Limestone and the Claiborne sands, Alabama River.*

1. Orbitoidal White Limestone of the usual character ....10 feet.
2. White Limestone, containing great numbers of *Scutella Lyelli* and other echinoderms ....10 feet.
3. Calcareous clay in two beds of five feet each, separated by three feet of soft, earthy White Limestone. Below this, a ledge of hard limestone three feet and eight feet of blue clay with fucoids, becoming more calcareous below, in all.. about 24 feet.

4. Ledge of hard, white limestone, followed by twenty feet or more of argillaceous, soft, white limestone, with thin projecting ledges of purer limestone at intervals. Resembles the Rotten Limestone of Cretaceous formation ....about 25 feet.
5. Bed of *Scutella Lyelli*, in three layers, the middle one ferruginous.... ......3 feet.
6. Coarse, ferruginous sand, calcareous below, hard ledge at bottom ....6 feet.
7. Claiborne ferruginous, fossiliferous sands, the counterpart of those at Claiborne Bluff ....10 to 12 feet.
8. Calcareous, sandy clay, with hard ledge in middle ....6 feet.
9. Sandy, clay marl, with *Ostrea sellæformis;* four or five hard ledges passing into greensand below...12 feet.

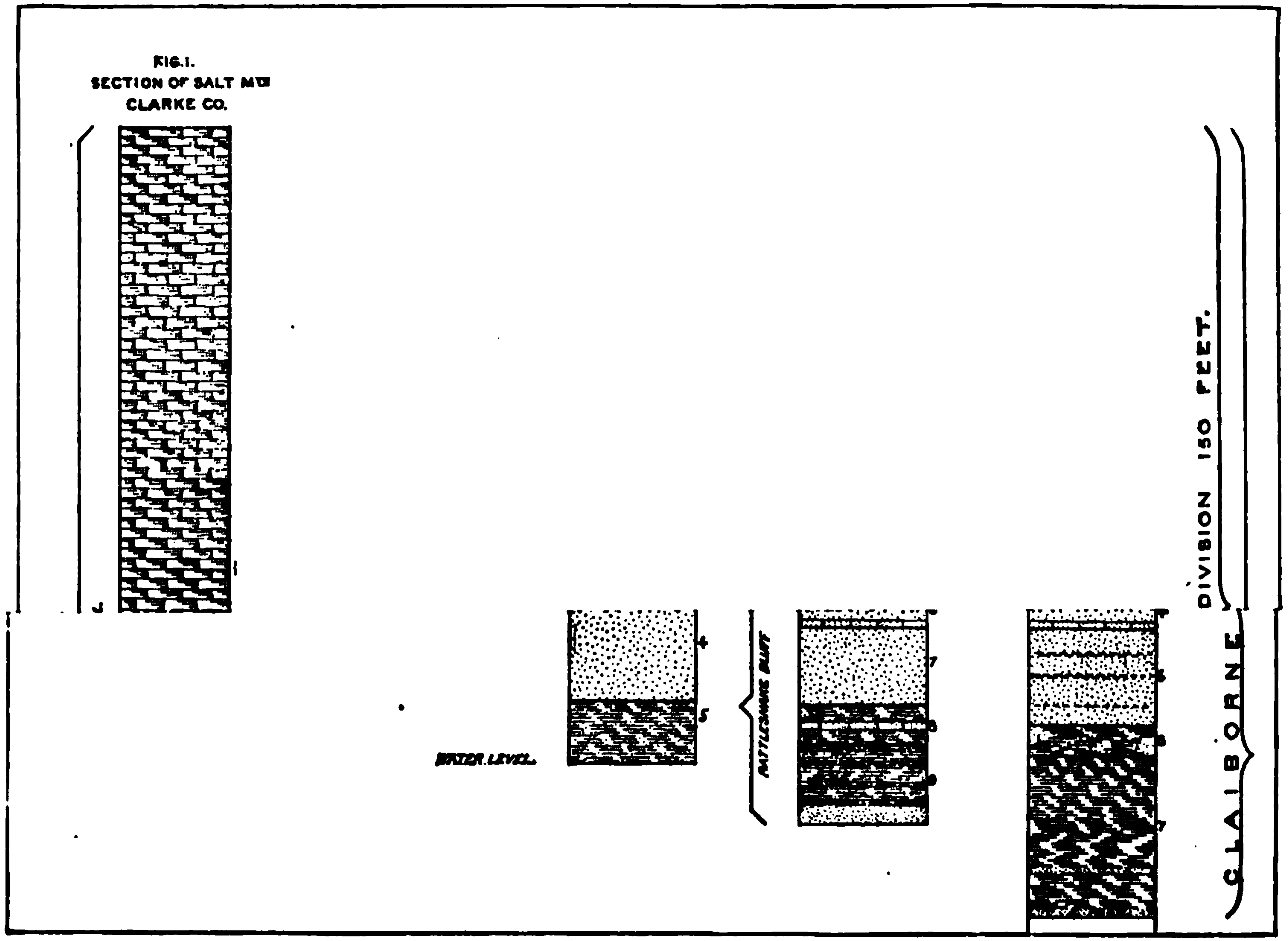
FIG. 5. *Section of upper part of bluff at Claiborne and of part of hill back of bluff, along the road to Perdue Hill, Alabama River.*

Hill back of river bluff.

1. White Limestone filled with *Orbitoides Mantelli*, occurring on road to Perdue Hill, 100 feet or more above top of bluff at Claiborne Landing. Tertiary strata covered by Drift along road leading from Perdue Hill up to Claiborne..90 to 100 feet.
Tertiary strata covered by Drift, at top of river bluff ....38 to 40 feet.

Upper part of bluff.

2. White or bright colored, argillaceous limestone with glauconite grains.....45 feet.
3. Indurated ledge of *Scutella Lyelli*..3 feet.
4. Coarse, ferruginous sand, calcareous below, indurated at base ....6 feet.
5. Claiborne fossiliferous sands, ferruginous. Lignitic in places above..15 to 17 feet.
6. Bluish green, glauconitic, sandy marl, with *Ostrea sellæformis*, part indurated.4 feet.
7. Calcareous, bluish gray clay, few badly preserved fossils, passing below into a greenish, glauconitic marl containing great numbers of young *Ostrea sellæformis* and a few *Pectens*, together about 18 feet; below this, light gray, calcareous clay, similar to top of preceding hard, sandy ledge at top and bottom, 7 feet; in all ....25 feet.



Scale: 1 inch = 40 feet.

PLATE XIII.

ILLUSTRATING THE CLAIBORNE STRATA AS EXPOSED ALONG THE ALABAMA AND TOMBIGBEE RIVERS.

FIG. 1. *Section by C. S. Hale.*

No. 8. White Limestone, thickness not given by Hale.

No. 7. Yellow, quartzose sand, highly fossiliferous; seam of earthy lignite near the middle........................15 feet.

No. 6. Clay bed, with shells of full grown *Ostrea sellæformis*................20 feet.

No. 5. Marly, arenaceous beds, with same shells as are common in the other beds; thickness not given by Hale.

No. 4. Argillaceous, muddy deposits. Fossils mostly oyster, except *Venericardia planicosta*, *Arca*, and *Turritella;* occurs also at Coffeeville................15 to 20 feet.

No. 3. Only a few feet at Claiborne; greensand running gradually into No. 4.

FIG. 2. *Section by Professor Tuomey.*

g. Red loam, sand, and pebbles........................30 feet.

f. White and mottled clay........................8 feet.

e. Limestone, with a small percentage of greensand........................54 feet.

d. Sandy, fossiliferous bed........................15 feet.

c. Whitish limestone, with bed on top containing *Ostrea sellæformis* and *Scutella Lyelli.* This bed passes below into a bluish marl with shells............12 feet.

b. Bed of clay, with limestone seam on top. This bed is more calcareous below and contains fossils that, as a group, are peculiar........................15 to 18 feet.

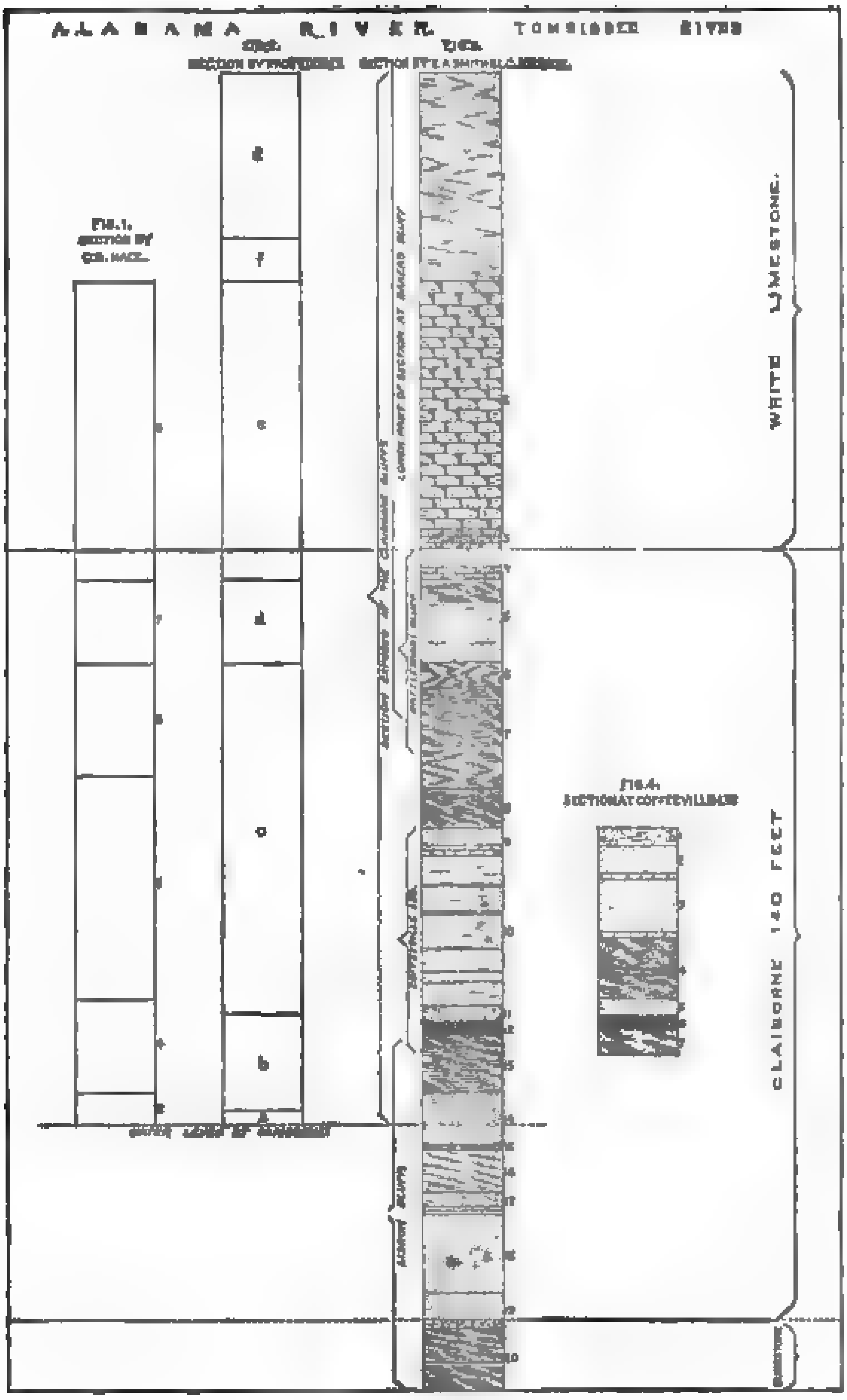
FIG. 3. *Section by E. A. Smith and L. C. Johnson.*

1. Red loam, sand, and pebbles........................35 to 40 feet.
2. Argillaceous limestone, with greensand grains........................45 feet.
3. Indurated ledge, with *Scutella Lyelli*........................3 feet.
4. Coarse, ferruginous sand, calcareous below; indurated ledge at base......6 feet.
5. Claiborne fossiliferous sands; ferruginous sands, with shells; laminated lignitic clays, with leaf impressions, and thin seams of lignite in places in upper part........................15 to 17 feet.
6. Bluish green, glauconitic sandy marl, containing *Ostrea sellæformis*, in part indurated........................3 to 4 feet.
7. Calcareous, bluish gray clay, with a few badly preserved fossils, passing downward into a greenish, glauconitic, sandy marl, containing great numbers of young shells of *Ostrea sellæformis* and a few *Pectens*, the two together, clay and sand........................about 18 feet.
8. Light gray, calcareous clay, similar to the preceding, with hard, sandy ledges at top and bottom, in all........................about 7 feet.
9. Light yellowish gray, calcareous sands, with *Pectens* and *Ostrea sellæformis*, the lower half indurated, containing casts of univalve shells..........about 5 feet.

10. Light yellowish gray, calcareous sands, with thin beds of more clayey texture and with five or six hard, sandy ledges at intervals; the sand is, in places, loose and crumbling, and quite fossiliferous, with *Ostrea sellæformis*, *Pecten Deshayesii*, fragment of *Scutella Lyelli*, &c., lower 8 feet a bluish, clayey sand..about 27 feet.
11. Bed of greensand, with perfect shells and fragments of *Ostrea sellæformis* &c.. about 3 feet.
12. Dark blue, nearly black, sandy clay..2 feet.
13. Bluish green, clayey sands, few fossils above, but highly fossiliferous below and rather more clayey, *Venericardia planicosta*, *Nucula magnifica*, *Ostrea sellæformis*, *Arca rhombodella*, *Voluta Sayana*, *Turritella Mortoni*, *T. bellifera*, &c....10 feet.
14. Dark grayish blue greensand, peculiar small form of *Venericardia planicosta*, large *Turritella Mortoni*, &c., 6 feet at Claiborne, but 10 feet at Lisbon.
15. Hard, sandy ledge.. 8 inches.
16. Calcareous, clayey sands, lighter yellowish to white color..................8 feet.
17. Coarse, ferruginous sands, with numerous fossils...........................3 feet.
18. Light yellow sands, capped with a hard ledge, forming perpendicular bluff. 15 feet.
19. Blue, glauconitic sands, probably a modification of 18......................5 feet.
20. Bluish black clay; top of Buhrstone contains curious concretions of sandy clay, like interlacing roots.

FIG. 4. *Section at Coffeeville Landing, Tombigbee River.*

1. Light yellowish sands, partly indurated, with *Ostrea sellæformis*, &c.........3 feet.
2. Loose, yellowish, calcareous sands, with *Ostrea sellæformis*. Indurated sand ledge at base.. 6 feet.
3. Loose, yellowish gray, calcareous sands, highly fossiliferous below, *Ostrea sellæformis* the chief form, separated from next by hard, sandy ledge..... ....10 feet.
4. Bluish, clayey sand, with *Ostrea sellæformis* and *Flabellum*, in two parts, separated by hard ledge: upper part, 8 feet; lower, 3 feet, in all ....12 feet.
5. Glauconitic sands, filled with comminuted and perfect shells of *Ostrea sellæformis*, &c ....3 feet.
6. Dark bluish black, non-fossiliferous, sandy clays ....2 feet.
7. Dark bluish green, clayey sand to water level.. ....5 feet



Scale 1 inch = 40 feet.

SECTIONS OF THE CLAIBORNE STRATA ALABAMA AND TOMBIGBEE RIVERS.

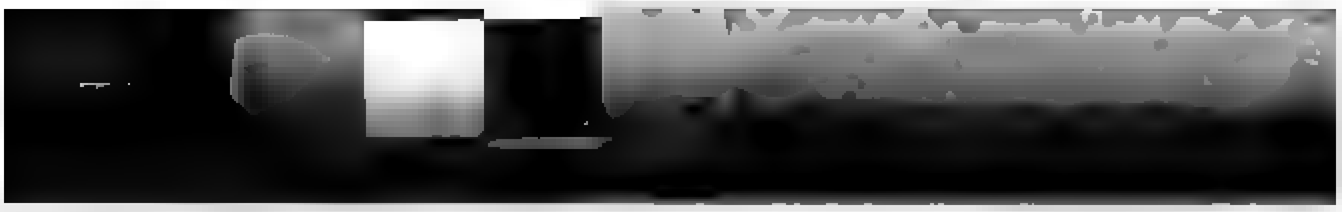


PLATE XIV.

SECTIONS OF THE BUHRSTONE STRATA WITH THE ADJACENT STRATA OF THE CLAIBORNE AND LIGNITIC.

FIG. 1. *Section at Lisbon, Alabama River.*

1. Light yellow sands, with glauconite, capped with hard ledge, lower 5 feet of bluish color, base of Claiborne rocks..20 feet.
2. Bluish black jointed clay, sandy concretions in upper part ....15 feet.

FIG. 2. *Section at Hamilton's Landing, Alabama River.*

1. Light gray, indurated clays and aluminous sandstones, with one or two indurated ledges, forming the whole of the bluff at Hamilton's Landing.............75 feet.

FIG. 3. *Section exposed along road leading up hill west of McCarthy's Ferry, Tombigbee River.*

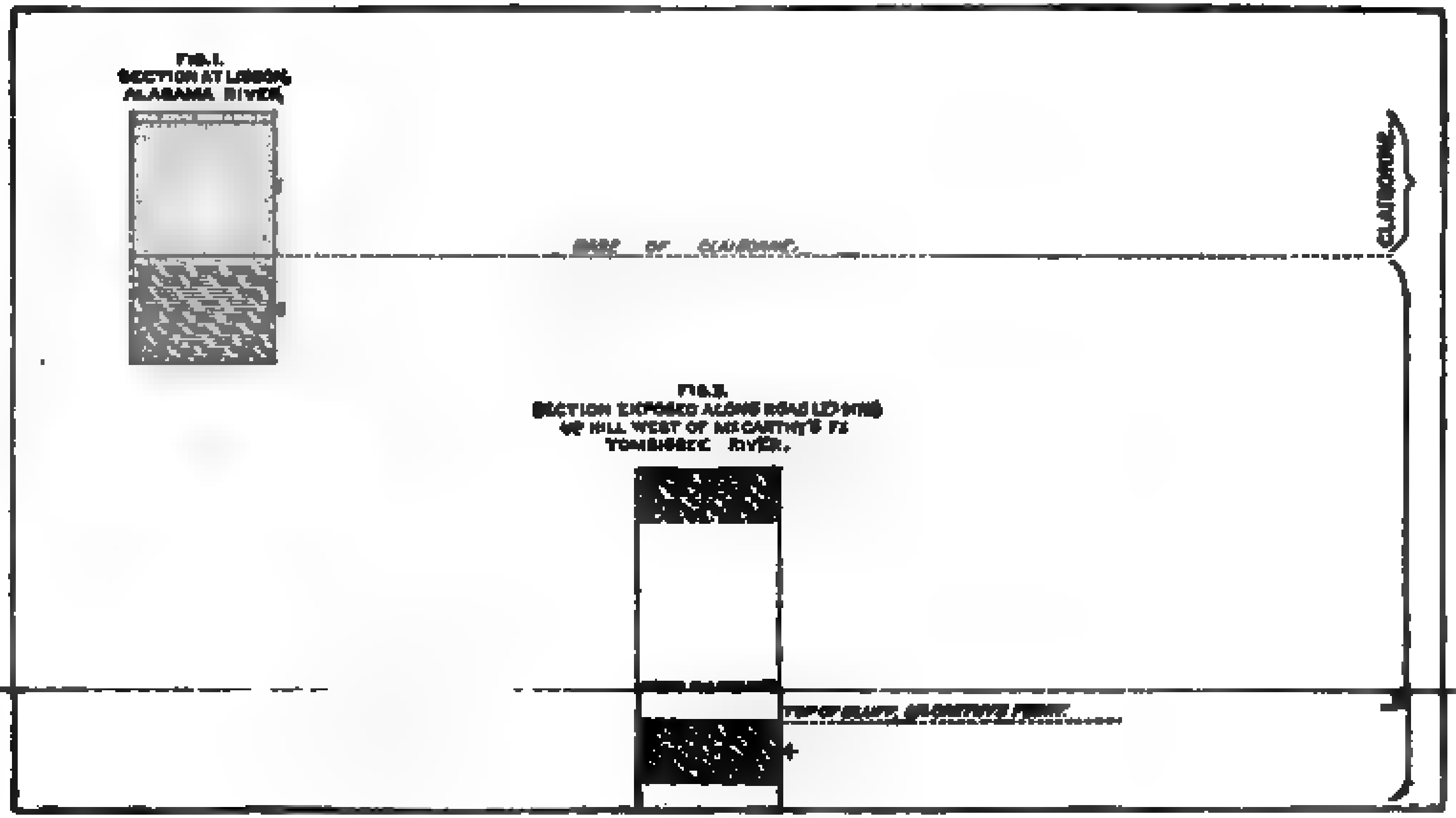
1. Top of hill west of McCarthy's Ferry, in Choctaw County. On the road down to the ferry 250 to 270 feet of Buhrstone rocks are passed over. These consist of indurated clays, claystones, and aluminous sandstones; the relative positions and order of succession of the different beds not intended to be represented in figures. These rocks appear at the surface at short intervals all the way exposed 270 feet.
2. Ledge of silicious sandstone or quartzite, interstratified with indurated clays.
3. Laminated clays, reddish and yellowish, just below Buhrstone rocks on road down the hill; strata exposed just back of bluff of river.
4. Sandy clays &c. (Continuation, see Fig. 3, Plate XV.)

FIG. 4. *Section of upper part of White Bluff, below Wood's Bluff, Tombigbee River.*

1. Aluminous sandstones and indurated clays with jointed structure, forming a clear, perpendicular bluff...115 feet.
2. Grayish, sandy clays, with a layer 18 inches thick at base, containing lignitized stems and twigs..20 feet.
3. Sandy clays, lignitic layer at base...5 feet.

FIG. 5. *Section of the upper part of Hatchetigbee Bluff, Tombigbee River.*

1. Light colored, aluminous sandstone and indurated clays...............20 to 30 feet.
2. Sandy clays, brown, yellow, and red, interstratified, bluish when wet, but lighter when dry ....20 feet.
3. Heavy bedded, brownish clays, darker than the preceding.................10 feet.



Scale: 1 inch = 40 feet

SECTIONS OF THE BUHRSTONE STRATA, WITH ADJACENT STRATA OF THE CLAIBORNE AND LIGNITIC

PLATE XV.

ILLUSTRATING THE HATCHETIGBEE SECTION OF THE LIGNITIC, BUT INCLUDING ALSO A PORTION OF THE LOWER PART OF THE BUHRSTONE AND THE UPPER PART OF THE WOOD'S BLUFF SECTION.

FIG. 1. *Section of White Bluff, Davis's Bluff, and Wood's Bluff, Tombigbee River.*

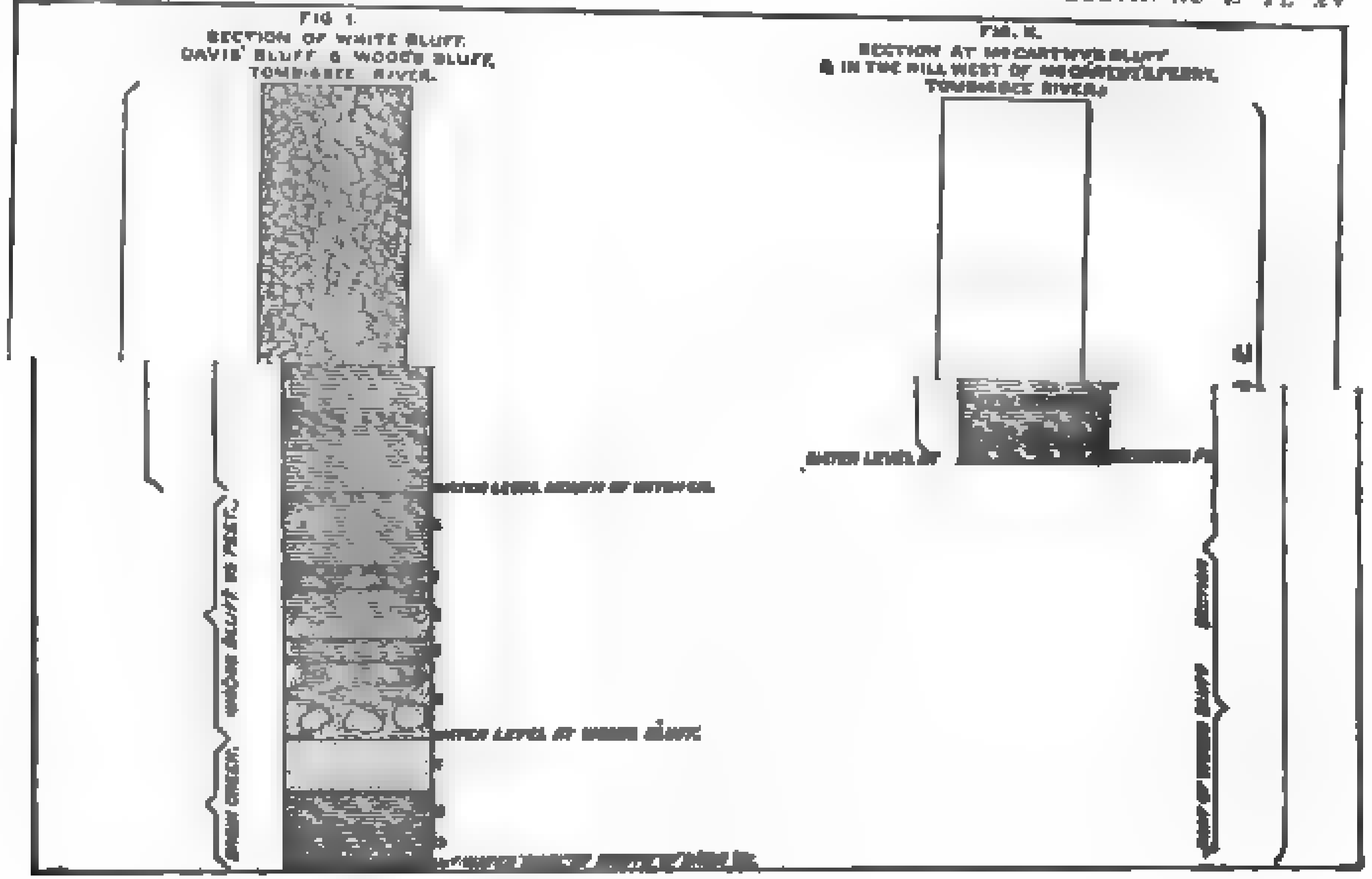
1. Buhrstone rocks, chiefly aluminous sandstones and indurated clays, with jointed structure and prevailing light gray colors, forming a perpendicular cliff. 115 feet.
2. Grayish, sandy clays, with a layer 18 inches thick at base, containing lignitic stems and twigs........20 feet.
3. Sandy clays, with lignitic layer at base........5 feet.
4. Strata obscured by landslides........65 feet.
5. Dark gray, sandy clays, striped with brownish purple bands of clay containing very few fossils, except in a thin band of marl 12 feet above the water and one 24 feet above the water, all exposed in Davis's Bluff........70 feet.
6. Dark gray to brown, sandy clays, between Wood's Bluff and Davis's Bluff..10 feet.
7. Bluish, sandy, fossiliferous clay, red on surface, hard ledge at top........3 feet.
8. Bluish, sandy clay, like No. 7, but not fossiliferous, passing into greensand below........7 feet.
9. Fossiliferous, clayey greensand........3 feet.
10. Greensand marl, with stratum of ponderous oyster shells, highly fossiliferous; tends to form rounded bowlders........10 feet.
11. Fossiliferous greensand, loose and easily washed out, forming caves under the bowlders........8 feet.
12. Thin band of lignite over greenish, non-fossiliferous, clayey sands........5 feet.
13. Laminated, gray, sandy clays........3 to 4 feet.
14. Lignite........8 feet or more.

FIG. 2. *Section at Hatchetigbee Bluff, Tombigbee River.*

1. Drift and surface materials, light colored, aluminous sandstones and indurated clays, Buhrstone rocks........20 to 30 feet.
2. Sandy clays of brown, yellow, and red colors, interstratified, blue when moist, lighter color when dry........15 to 20 feet.
3. Heavy bedded, brownish clays of darker color than No. 2........10 feet.
4. Yellowish, glauconitic marl........3 feet.
5. Purplish brown, sandy clays, with band of hard, dark colored clays in middle, projecting........15 feet.
6. Yellowish gray sands, striped with brown clays, forming bowlders at intervals........6 feet.
7. Blue clay marl, sandy, many new forms........5 feet.
8. Grayish sands striped with brown clay bands, bowlders........4 feet.
9. Heavy bedded, gray, sandy clays, with brown clay stripes, indurated at base. 8 feet.
10. Reddish, fossiliferous sand, *Venericardia planicosta* abundant........5 feet.
11. Dark gray to brown, sandy clays, to water's edge........15 feet.

FIG. 3. *Section at McCarthy's Ferry, Tombigbee River.*

1. Buhrstone rocks exposed along road leading up the hill from McCarthy's Ferry. See Fig. 3, Pl. XIV.
2. Laminated clays, reddish and yellowish, containing an indurated greensand marl with Hatchetigbee fossils, exposed in hill above the bluff and intervening between the strata seen in the river bluff and the aluminous rocks of the Buhrstone seen higher up the hill.
3. Sandy clays interstratified with clays less sandy, light gray, along the whole length of the bluff. There are parallel bands of much darker brown clays... 55 feet.
4. Laminated clays and sands, firm and compact at base, and forming projecting ledge.. 5 feet.
5. Pyritous sandy clays, with two or three bands of darker color, indurated in places, forming bowlders..20 feet.



Scale, 1 inch = 40 feet.

HATCHETIGBEE SECTION OF THE LIGNITIC, WITH PARTS OF THE BUHRSTONE AND WOOD'S BLUFF

PLATE XVI.

ILLUSTRATING THE WOOD'S BLUFF OR BASHI AND BELL'S LANDING SECTIONS OF THE LIGNITIC, AND INCLUDING THE LOWER BEDS OF THE HATCHETIGBEE SECTION.

FIG. 1. *Section at Yellow Bluff, Alabama River.*

1. Gray, sandy clays, with cross bedded sands. Forty feet seen in one exposure in river bank and 90 feet more seen on the hills within 1 mile of the river. Only the lower 40 feet occurring at river are here shown .... 40 feet.
2. Greensand marl, Wood's Bluff fossils .... 6 feet or more.
3. Blue clay .... 1 foot.
4. Gray, sandy clays of slightly purple tinge, containing four or five thin seams of lignite .... 40 feet.
5. Reddish, cross bedded sand .... 20 feet.
6. Lignitic clay and lignite .... 2 feet.
7. Reddish sands, slightly laminated .... 15 feet.
8. Gray, sandy clays, laminated, forming perpendicular cliff .... 25 feet.
9. Greensand marl, indurating into bowlders, Bell's Landing fossils .... 8 feet.
10. Greenish, ferruginous sands interlaminated with thin sheets of clay to water level .... 7 feet.

FIG. 2. *Section at Bell's Landing, Alabama River.*

1. Yellowish, cross bedded sands .... 15 feet.
2. Lignite .... 2 feet.
3. Laminated, sandy clays, with a few large, bowlder like concretions .... 10 feet.
4. Yellow, stratified sands, alternating with gray, sandy clays .... 15 feet.
5. Gray, sandy clays, laminated .... 15 feet.
6. Greensand marl, forming bowlders, gigantic shells .... 6 to 10 feet.
7. Dark gray, laminated, sandy clays .... 25 feet.
8. Sandy, clay marl .... 1 to 2 feet.
9. Dark gray, sandy clay to water level .... 4 feet.

FIG. 3. *Section at Peebles's Landing, Alabama River.*

1. Yellowish sands .... 1 to 2 feet.
2. Lignite and lignitic clay .... 2 feet.
3. Reddish sands, laminated .... 10 feet.
4. Gray clays and sands, variously interstratified .... about 30 feet.
5. Greensand marl, forming bowlders, Bell's Landing fossils .... 8 feet.
6. Dark gray, sandy, laminated clays .... 25 feet.
7. Strata covered by second bottom deposits, down to water level .... 20 feet.

FIG. 4. *Section at Gregg's Landing, Alabama River.*

1. Greensand marl, forming bowlders, Bell's Landing fossils .... 8 to 10 feet.
2. Gray, sandy, laminated clays .... 20 to 25 feet.
3. Sandy clay marl, fossiliferous .... 4 to 5 feet.
4. Laminated, sandy clays to water level .... 10 feet.

FIG. 5. *Section at Lower Peach Tree Landing, Alabama River.*

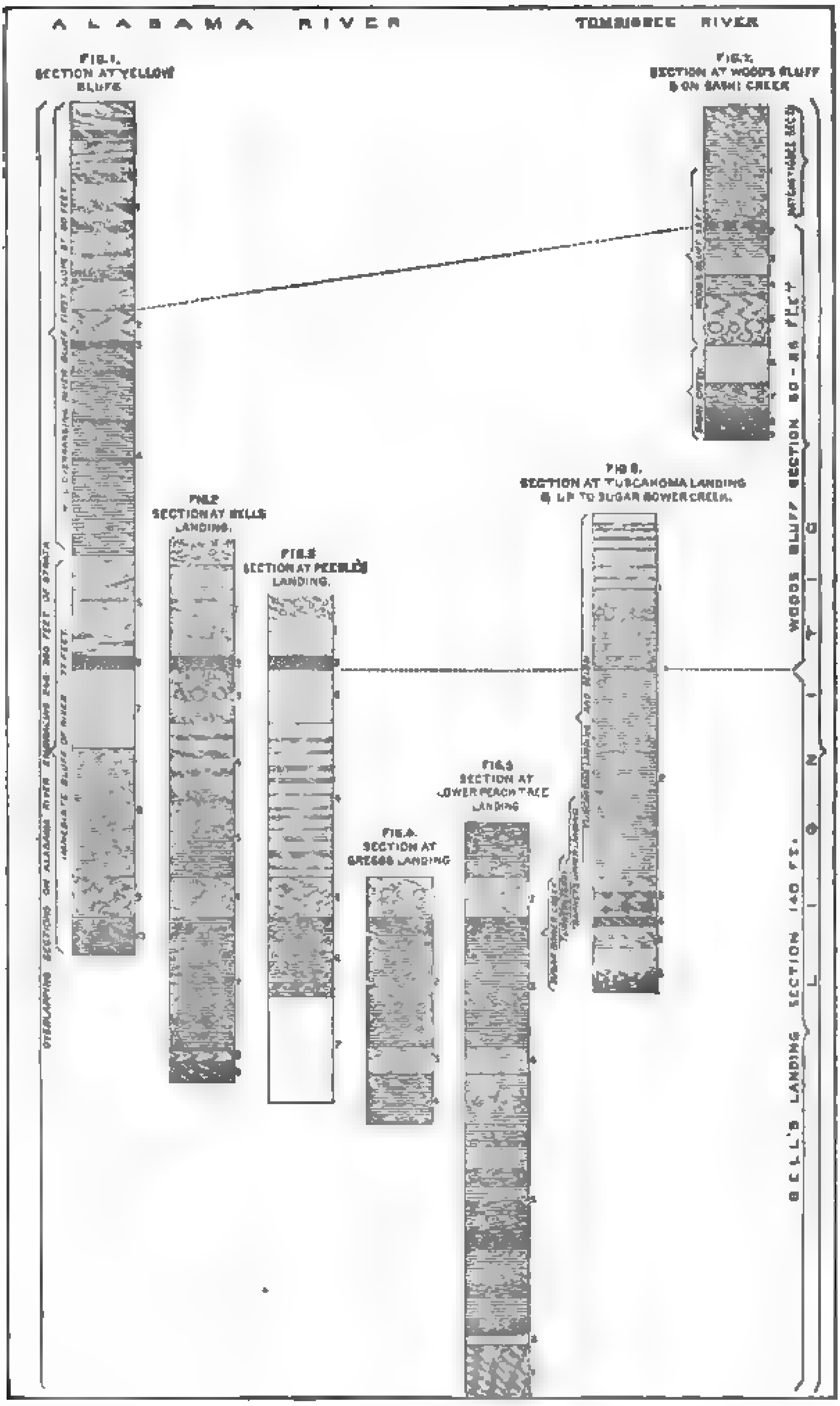
1. Sandy, laminated clays, top of bluff ....10 feet.
2. Greensand marl, forming bowlders, Bell's Landing fossils..............8 to 10 feet.
3. Laminated, sandy clays of gray color but with reddish layers ....20 to 25 feet.
4. Bluish, sandy clay marl, Gregg's Landing fossils.....................4 to 5 feet.
5. Sandy clays of prevailing gray color, varying in degree of sandiness and coarseness of lamination. No fossils observed ....50 feet.
6. Fossiliferous greensand...1 foot.
7. Gray, sandy clays to water level...10 feet.

FIG. 6. *Section at Tuscahoma Landing and up to Shuquabowa Creek, Tombigbee River.*

1. Laminated sands, interstratified with clayey sheets, upper part; lower part, indurated sands with two lines of ferruginous, bowlderlike concretions, one at base, the other ten feet above ....30 feet.
2. Light bluish gray, sandy clays, striped with somewhat harder projecting bands or ledges ....35 to 40 feet.
3. Greensand marl, Bell's Landing fossils; three feet blue clay in middle..6 to 7 feet.
4. Bluish black, massive clay ....2 feet.
5. Sands passing into sandy clays below ....5 feet.
6. Lighter colored, cross bedded sands above, with sands and clay interstratified below ....8 feet.

FIG. 7. *Section at Wood's Bluff and Bashi Creek, Tombigbee River.*

1. Dark gray to brown and purple, sandy clays, lower beds of Hatchetigbee section.
2. Bluish, sandy, fossiliferous clay, red on surface, hard ledge on top ....3 feet.
3. Bluish, sandy clay (like 2), but not fossiliferous, passing into greensand below.7 feet.
4. Fossiliferous, clayey greensand...3 feet.
5. Greensand marl, main bed, with a stratum of ponderous oyster shells; highly fossiliferous sands forming bowlders ....10 feet.
6. Fossiliferous greensand, loose and easily washed out, forming caves below the bowlders ....8 feet.
7. Thin bands of lignite over greenish, non-fossiliferous, clayey sands..........5 feet.
8. Laminated, gray, sandy clays ....3 to 4 feet.
9. Lignite ....1 foot.



Scale 1 inch = 4 feet

WOOD'S BLUFF OR BASHI SECTION AND BELL'S LANDING SECTION OF THE LIGNITIC

PLATE XVII.

ILLUSTRATING THE NANAFALIA AND COAL BLUFF SECTIONS OF THE LIGNITIC.

FIG. 1. *Sections at Gullette's Bluff and Coal Bluff, Alabama River.*

Gullette's Bluff.

1. Red loam, sand, &c., of Drift, at the top of the bluff .... 10 feet.
2. Indurated, glauconitic clay .... 3 feet.
3. Gray, sandy clays, alternately thinly laminated and heavy bedded or massive .... 12 feet.
4. Very green, glauconitic sand .... 2 feet.
5. Gray, sandy clays, similar to No. 3 above .... 20 feet.
6. Fossiliferous, glauconitic sand, first of *Gryphæa thirsæ* beds .... 3 feet.
7. Compact, yellowish sands with *Gryphæa thirsæ*, capped by hard ledge, forming vertical cliff .... 13 feet.
8. Indurated sands .... 2 feet.
9. White, cross bedded sands .... 12 feet.
10. Bluish sands in a vertical cliff; contains *Gryphæa thirsæ*; indurated ledge in middle and at bottom of the bed .... 20 feet.
11. Bluish, clayey sands, with *Gryphæa* .... 10 feet.
12. Sands with *Gryphæa thirsæ*, traversed by several indurated ledges down to water level; darker colored and more clayey below .... 20 feet.

Between mouth of Pursley Creek and Coal Bluff.

13. Greensand, mouth of Pursley Creek .... 5 feet.
14. Sands capped with indurated ledge .... 3 feet.
15. Clayey sands; indurated sandy ledges at top and in the midst .... 6 feet.
16. Indurated greensand .... 3 feet.
17. Softer greensand, out of which caves are washed .... 5 feet.
18. Greensand of firmer texture, with 1 foot of brownish sand at bottom .... 8 feet.
19. Lignite of Coal Bluff .... 4 feet.
20. Firm, gray, sandy clays appearing just above Coal Bluff Landing .... 10 feet.

FIG. 2. *Section in Grampian Hills, 2 to 3 miles south of Camden, Wilcox County.*

1. Light colored sand and clayey rocks 2 feet, and 2 feet sandstone with shell casts .... 4 feet.
2. Gray clays, indurated, closely resembling Buhrstone .... 10 to 15 feet.
3. Light colored, sandy clay rock, full of shell casts, chiefly *Turritella* .... 5 feet.
4. Gray crumbling clays, weathering into small bits .... 5 to 6 feet.
5. Hard, glauconitic, sandy clay with shell casts breaking into cuboidal blocks .. 3 feet.
6. Gray, indurated clays, glauconitic in places, and like some of the Buhrstone clays .... 12 to 15 feet.
7. Greensand, with casts of *Gryphæa thirsæ* .... 2 feet.
8. Greensand, in places converted into a yellowish sand, holding the *Gryphæa thirsæ* .... 10 feet.

9. Yellow sands, with *Gryphæa* ....5 feet.
10. Bed of *Gryphæa* shells ....1 foot.
11. Yellow sands, with *Gryphæa*, and forming bowlders, 6 to 8 feet; in all..12 to 14 feet

FIG. 3. *Section on Pursley Creek, Wilcox County, Camden and Black's Bluff road.*

1. Red loam, sand, &c., of Drift.
2. Dark colored, crumbling sandy clays..5 feet.
3. Sands, with *Gryphæa thirsæ* and a few other fossils........................5 to 7 feet.
4. Thin bedded sands and sandy clays..15 feet.
5. Yellowish gray, cross bedded sands, with indurated bowlders of same materials; these sands hold also thin, lenticular sheets of gray clay........................25 feet.
6. Interstratified sands and clays of grayish color, with shades of yellow, rather thin-bedded ....15 feet.
7. Gray, sandy clays in banks of Pursley Creek..6 feet.
8. Lignite or lignitic clay, bed of Pursley Creek.

FIG. 4. *Strata exposed on Tombigbee River from mouth of Horse Creek up to Nanafalia; also section on Landrum's Creek.*

Mouth of Horse Creek to Gay's Landing.

1. Gray, sandy clays, forming banks of river between mouth of Horse Creek and Williams's Gin, and directly overlying the bed at the last named place.20 feet.
2. Gray, sandy clays, thin bedded, and in joint planes, passing below into a hard, sandy ledge ....8 feet.
3. Indurated greensand, with *Gryphæa thirsæ*..2 feet.
4. Dark blue black clays, with thin, firm ledges..6 feet.
5. Indurated sands, with *Gryphæa thirsæ*..2 feet.
6. Bluish black, sandy clays..3 feet.
7. Greensand, with *Gryphæa thirsæ*, passing below into gray, sandy clay. 5 feet or more.

Lott's Ferry.

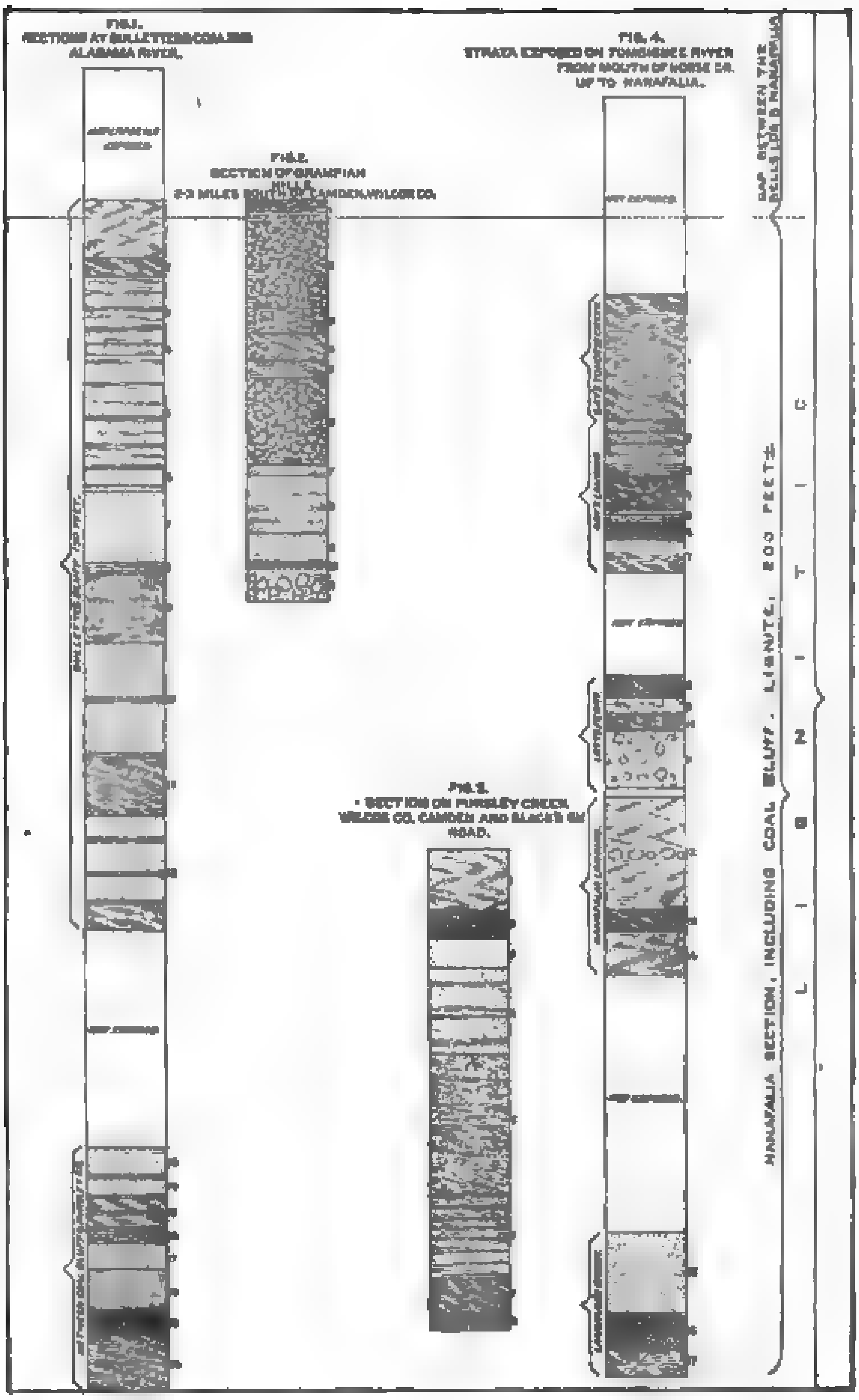
8. Black, sandy clay, fossiliferous ....4 feet
9. Sands, with *Gryphæa thirsæ*, cross bedded in places ....3 feet
10. Dark gray, sandy clay, with few fossils ....3 feet
11. Greensand, with *Gryphæa thirsæ*, forming hard bowlders in places. ....10 feet.

Nanafalia Landing.

12. Greensand marl, highly fossiliferous, with *Gryphæa thirsæ* and other forms; line of indurated, projecting bowlders along central part of bed............20 feet
13. Dark blue, almost black, laminated clay, devoid of fossils............3 to 4 feet.
14. Bluish greensand marl, highly fossiliferous below, *Gryphæa thirsæ* and other forms..8 to 10 feet

Landrum's Creek.

15. Bluish, micaceous sands overlying lignite on Landrum's Creek, near Nanafalia Bluff ....15 feet.
16. Lignite exposed on Landrum's Creek..7 feet.
17. Gray, sandy clays ....5 feet.



Scale. 1 inch = 40 feet.

NANAFALIA AND COAL BLUFF SECTION OF THE LIGNIT C

PLATE XVIII.

ILLUSTRATING THE OAK HILL, PINE BARREN SERIES, WHICH INCLUDES THE NAHEOLA AND MATTHEWS'S LANDING, BLACK BLUFF. AND THE MIDWAY SECTIONS OF THE LIGNITIC.

FIG. 1. *Section at Oak Hill and on Pine Barren Creek.*

1. Cross bedded sands and thinly laminated clays, much weathered and with difficulty distinguished from the red loam &c. of the Drift................25 feet.
2. Gray, cross bedded sands, with thin laminæ of dark gray clay. These beds are much the same as the preceding, but are much less weathered................40 feet.
3. Cross bedded and laminated sands, yellowish..........................1½ feet.
4. Thin bedded, gray, laminated clays, interstratified with thin ledges of cross bedded sands..30 feet.
5. Sands 1 foot, clays 1 foot, sands 1 foot..................................3 feet.
6. Gray clays interstratified with cross bedded sands.......................6 feet.
7. Gray, cross bedded sands..3 feet.
8. Gray clay, breaking up into cuboidal blocks, and interstratified with sandy ledges...15 feet.
9. Black to gray, micaceous sands, with the fossils of Matthews's Landing, dark at top, lighter and glauconitic below......................................7 feet.
10. Glauconitic sandy ledge, calcareous.......................................1 foot.
11. Yellowish, calcareous sands, with phosphatic and white lime concretions; crustacean remains in upper 5 feet; several hard, shaly ledges..............12 feet.
12. Glauconitic, sandy shales, with indurated ledge at top....................10 feet.
13. Sandy, shaly beds, with indurated ledges..................................6 feet.
14. Hard, yellowish, sandy limestone, phosphatic..............................3 feet.
15. Yellowish, calcareous, clayey sands, with white lime concretions, grayer and more clayey below; Black Bluff fossils abundant......................15 feet.
16. Black, calcareous clays, gray on weathered surfaces; Black Bluff fossils, especially in upper part. This forms basis of the prairie soils..............20 feet.
17. Hard, grayish white limestone, used for chimneys, &c., containing a large *Nautilus*..10 feet.
18. Calcareous sands forming basis of the sandy prairies......................6 feet.
19. Hard, yellow, crystalline limestone, with Ostrea, *Turritella Mortoni*, and *Venericardia planicosta*..8 feet.
20. Yellow, micaceous sands, with Ripley fossils—seen on road above Palmer's Mill..55 feet.
21. Bluish gray, calcareous sands, with projecting sandy ledges, on Pine Barren Creek..15 feet.

FIG. 2. *Section on the Alabama River.*

Coal Bluff.

1. Bluish greensand over lignite.
2. Coal Bluff lignite...4 feet.
3. Compact, clayey sand underlying lignite.

Burford's Landing.

4. Gray, cross bedded sands alternating with laminæ of gray clay, Burford's Landing .... 10 feet.

Walnut Bluff.

5. Light yellowish, cross bedded sands, Walnut Bluff.

Turkey Creek to Clifton.

6. Gray or bluish, sandy clays, forming river banks from mouth of Turkey Creek to Clifton, of variable dip and hence of undetermined thickness.
7. Dark, gray sandy clays at Clifton and above, nearly to mouth of Dickson's Creek. The beginning of the Matthews's Landing beds .... 10 feet.

Matthews's Landing.

8. Bluish black, micaceous sands, highly fossiliferous .... 5 to 6 feet.
9. Yellowish gray, calcareous sands, indurating into bowlders................ 4 feet.
10. Bluish black, micaceous sands, fossiliferous, compact and clayey below. 7 to 8 feet.

Midway.

11. Black, calcareous clay overlying the Nautilus Rock...................... 5 feet.
12. Gray, argillaceous limestone, with numerous large *Enclimatoceras Ulrichi*.. 10 feet.

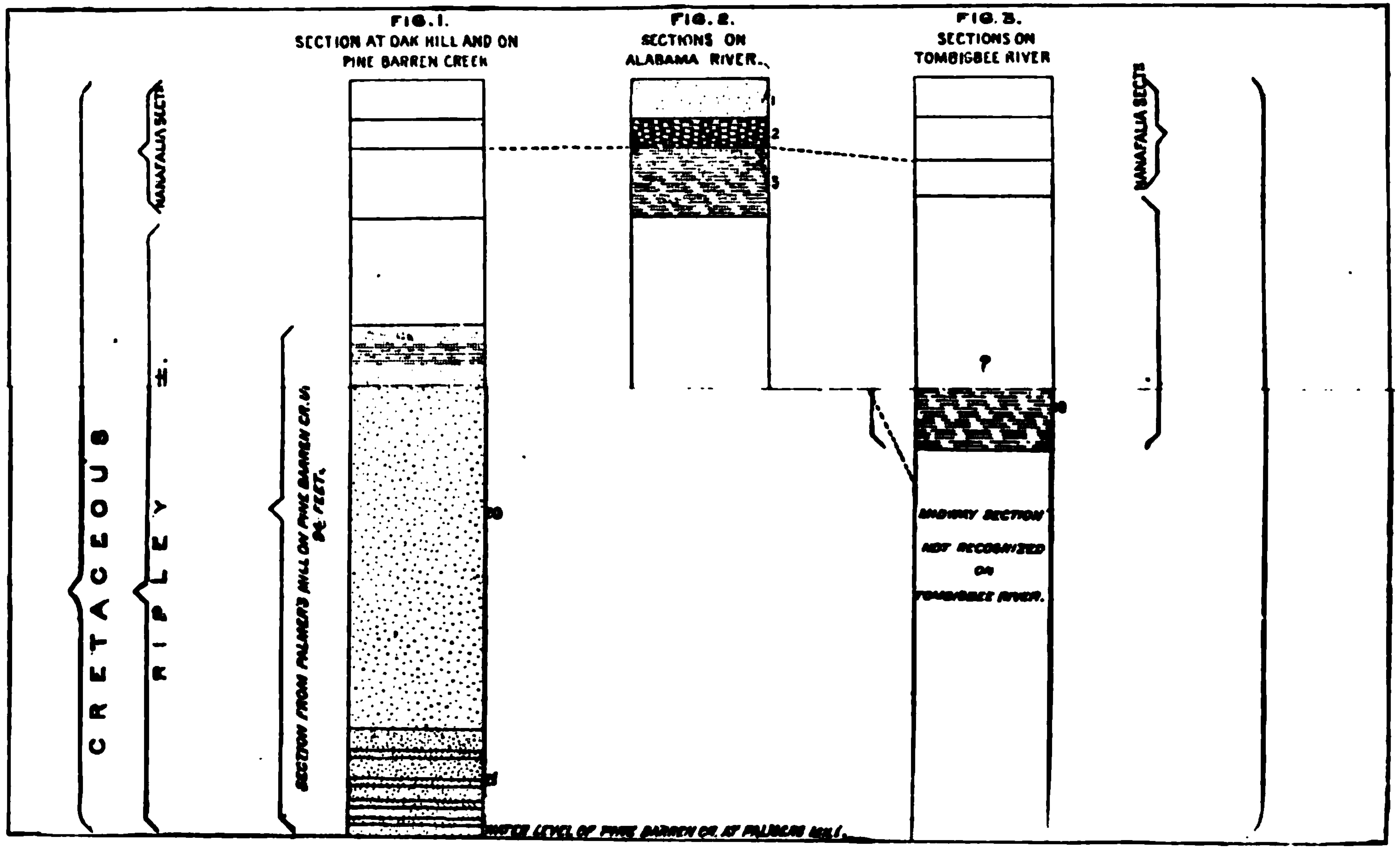
FIG. 3. *Sections on the Tombigbee River.*

Mouth of Beaver Creek to Nahcola.

1. Coarse grained, micaceous sands, with projecting bowlders of indurated sand or sandstones, no fossils, thin clay partings at intervals, seen just below Tompkinsville .... 20 feet.
2. Cross bedded sands, just below Tompkinsville............................10 feet.
3. Gray, sandy clays, alternating with ledges of indurated sand and thin clay partings, Tompkinsville Bluff, no fossils.....................................30 feet.
4. Gray, sandy clays, with ledges of sandier texture and lighter color.......20 feet.
5. Black, sandy clay, with indurated ledge of greensand above, in all....... 3 feet.
6. Greensand marl, capped with hard ledge, ferruginous..................... 3 feet.
7. Black, slaty clay, recurring at all the bluffs above this to Black Bluff.....10 feet.

Black Bluff.

8. Yellowish clay at top of bluff. This clay is the basis of the Flatwoods.....30 feet.
9. Black, slaty clay, strongly calcareous, fossiliferous (Black Bluff fossils).. 40 feet.
The lower part of this division is covered with singularly shaped concretions of limonite.
10. Brownish, shaly clay to the water level. ....10 feet.



Scale: 1 inch = 40 feet

OAK HILL, PINE BARREN SERIES OF THE LIGNITIC, INCLUDING THE NAHEOLA AND MATTHEWS'S LANDING, THE BLACK BLUFF, AND THE MIDWAY SECTIONS.

Burford's Landing.

4. Gray, cross bedded sands alternating with laminæ of gray clay, Burford's Landing...10 feet.

Walnut Bluff.

5. Light yellowish, cross bedded sands, Walnut Bluff.

Turkey Creek to Clifton.

6. Gray or bluish, sandy clays, forming river banks from mouth of Turkey Creek to Clifton, of variable dip and hence of undetermined thickness.
7. Dark, gray sandy clays at Clifton and above, nearly to mouth of Dickson's Creek. The beginning of the Matthews's Landing beds ....10 feet.

Matthews's Landing.

8. Bluish black, micaceous sands, highly fossiliferous ....5 to 6 feet.
9. Yellowish gray, calcareous sands, indurating into bowlders................ 4 feet.
10. Bluish black, micaceous sands, fossiliferous, compact and clayey below.7 to 8 feet.

Midway.

11. Black, calcareous clay overlying the Nautilus Rock .... 5 feet.
12. Gray, argillaceous limestone, with numerous large *Enclimatoceras Ulrichi*..10 feet.

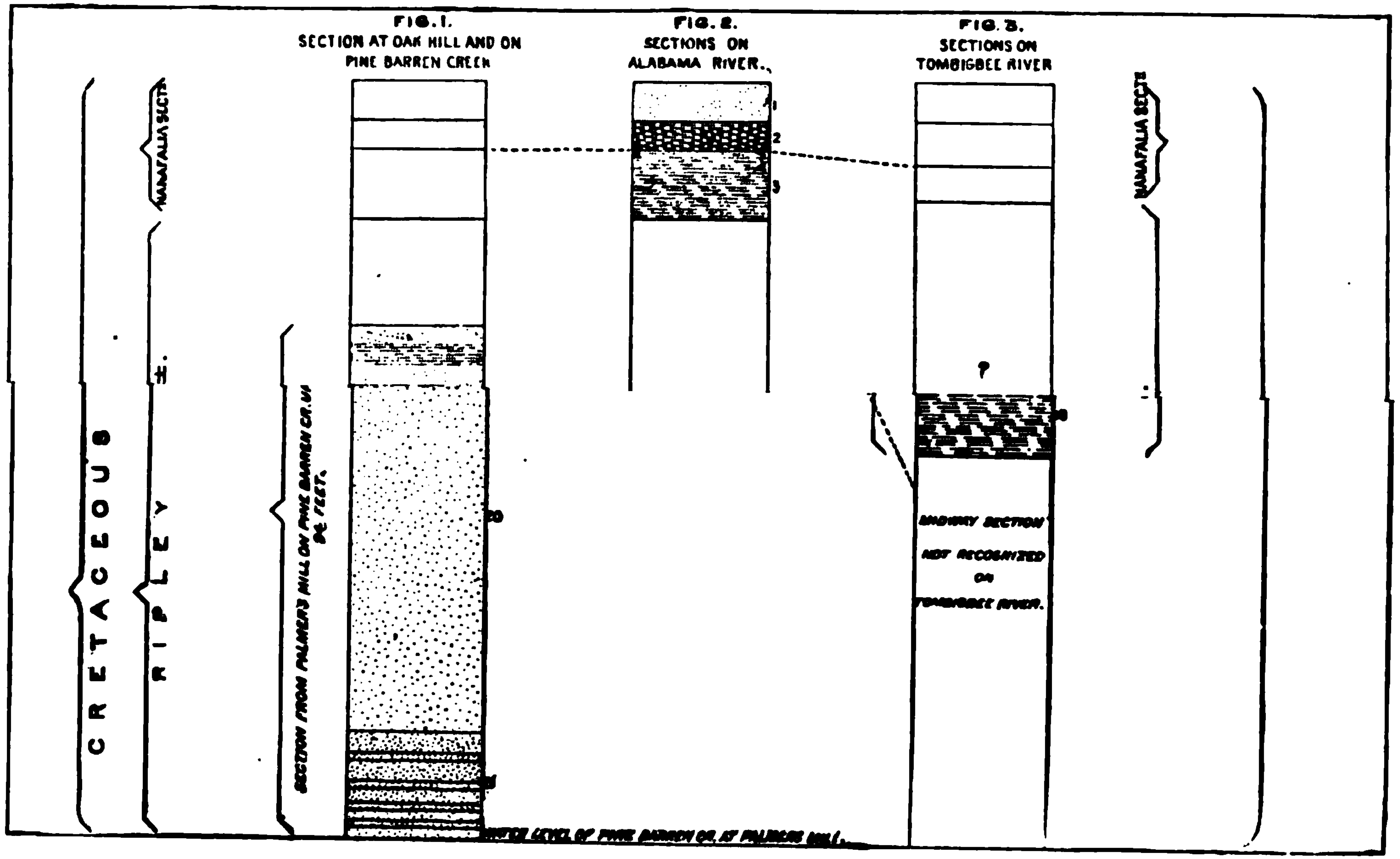
FIG. 3. *Sections on the Tombigbee River.*

Mouth of Beaver Creek to Naheola.

1. Coarse grained, micaceous sands, with projecting bowlders of indurated sand or sandstones, no fossils, thin clay partings at intervals, seen just below Tompkinsville ....20 feet.
2. Cross bedded sands, just below Tompkinsville..............................10 feet.
3. Gray, sandy clays, alternating with ledges of indurated sand and thin clay partings, Tompkinsville Bluff, no fossils...30 feet.
4. Gray, sandy clays, with ledges of sandier texture and lighter color. .... 20 feet
5. Black, sandy clay, with indurated ledge of greensand above, in all ...... 3 feet
6. Greensand marl, capped with hard ledge, ferruginous....... .... 3 feet
7. Black, slaty clay, recurring at all the bluffs above this to Black Bluff.....10 feet.

Black Bluff.

8. Yellowish clay at top of bluff. This clay is the basis of the Flatwoods.....30 feet.
9. Black, slaty clay, strongly calcareous, fossiliferous (Black Bluff fossils).. 40 feet
The lower part of this division is covered with singularly shaped concretions of limonite.
10. Brownish, shaly clay to the water level ....10 feet.



Scale: 1 inch = 4 feet

OAK HILL, PINE BARREN SERIES OF THE LIGNITIC, INCLUDING THE NAHEOLA AND MATTHEWS'S LANDING, THE BLACK BLUFF, AND THE MIDWAY SECTIONS.

PLATE XIX.

ILLUSTRATING THE RIPLEY FORMATION OF THE CRETACEOUS GROUP, ALABAMA AND TOMBIGBEE RIVERS.

FIG. 1. *Palmer's Mill, on Pine Barren Creek.*

1. Hard, yellow, crystalline limestone, with *Ostrea*, corals, *Turritella Mortoni*, *Venericardia planicosta*, &c....8 feet.
2. Yellow, micaceous sands, with Ripley fossils, seen on road above Palmer's Mill....55 feet.
3. Bluish gray, calcareous sands, with several projecting sandy ledges, to level of Pine Barren Creek....15 feet.

FIG. 2. *Bridgeport Landing, Alabama River.*

1. Yellow, crystalline limestone, seen in Camden-Bridgeport road.
2. Yellowish, micaceous sands, forming basis of the hills back of the Bridgeport Bluff.
3. Yellow, clayey sands, top of bluff at Bridgeport Landing....10 feet.
4. Coarse, yellow sands....10 feet.
5. Laminated, gray clays....1 foot.
6. Ledge of dark gray, sandy clay....1 foot.
7. Dark gray, nearly black, sandy, micaceous clays, with hard, projecting, sandy ledges at intervals of 3 to 4 feet....22 feet.
8. Projecting, sandy ledge....1½ feet.
9. Dark gray, sandy clays....3 feet.
10. Sandy ledge....1 foot.
11. Dark gray, sandy clays, with two hard, sandy ledges, to water level....10 feet.

FIG. 3. *Canton Landing, Alabama River.*

1. Yellow sands, forming basis of the fertile soils of the Canton Bend.
2. Yellowish gray, micaceous, and calcareous sands, in beds averaging 3 to 5 feet in thickness and separated by hard, sandy ledges, which shale off on weathering; these beds appear at intervals on hillside immediately back of the river bluff, being in part covered by débris....100 feet.
   In places the clayey sands have a dark blue color.
3. Yellow, calcareous, sandy clays, like the preceding, with hard ledges above and below; top of river bluff....10 feet.
4. Bluish, micaceous, sandy clays, the counterpart of those at Bridgeport, with two projecting, sandy ledges....12 feet.
5. Light gray, calcareous sands, holding indurated, irregular masses, phosphatized shell casts, &c.; sandstone ledge at base....6 feet.
6. Bluish gray, sandy clay, 5 feet thick, underlaid by more sandy bed, with phosphatized shell casts, nodules, &c....8 feet.
7. Bluish, argillaceous limestone, with *Exogyra*, *Gryphæa*, and phosphatic casts....3 feet.
8. Calcareous sands, with variety of fossils....3 feet.

FIG. 4. *Foster's Creek, in Gee's Bend, Alabama River.*

1. Yellowish, calcareous, sandy clay soil, with growth of red cedars.
2. Dark gray, micaceous, sandy clays, like those of Bridgeport, with hard, sandier ledges of lighter color at intervals of 5 to 6 feet. The lowermost of these beds contain the small Moscow *Gryphæa*....30 feet.

Impure limestone, glauconitic, with phosphatized shell casts &c. ....5 feet.
Coarse, calcareous sandstone ledge ....2 feet.
Bluish, sandy, argillaceous limestone, no fossils at top, but filled in its lower and middle parts with shells and phosphatized shell casts. The materials of this bed vary from argillaceous limestone to calcareous sands....................20 feet.
Brown, phosphatic limestone ....1 foot.
Argillaceous sandstone ....1 foot.

FIG. 5. *Section on Tear Up Creek, Wilcox County, Alabama River.*

Yellow sands at base of McNeill's Mountain.
Dark bluish gray, sandy, micaceous clays, with hard, projecting ledges at intervals of 3 or 4 feet. These beds are exposed in channel of Tear Up Creek between the river and the foot of McNeill's Mountain, distance about 1 mile. The thickness not measured, but here placed equal to that noticed at Canton Landing ....100 feet.
Ferruginous, sandy marl, full of Ripley fossils ....3 feet.
Firm white limestone; no fossils observed ....6 feet.
White limestone, with a few fossils ....2 feet.
Sandy, calcareous beds, with fine fossils ....4 feet.
Sandy, indurated limestone ledge ....1 to 2 feet.
Calcareous limestone, with *Exogyra costata* &c ....8 feet.

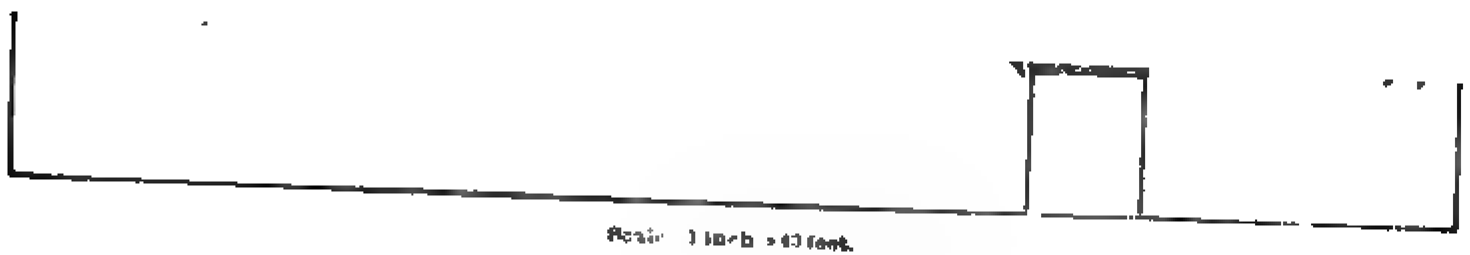
FIG. 6. *Prairie Bluff and hill to the northeast, Alabama River.*

Yellowish, calcareous, and micaceous sands, with hard, sandy ledges at intervals of 4 or 5 feet, forming the hill northeast of Prairie Bluff towards Rehoboth. In some places, where less exposed to weathering, the color of the sandy clays is dark bluish, like those of Bridgeport. The strata of this hill are in appearance identical with those above the river bluff at the old Canton Landing, not a continuous section...... ....75 to 100 feet, perhaps more.

2. Impure limestone, holding phosphatized shell casts &c, outcropping on the bluff north of warehouse; extended thickness...........................12 to 15 feet.
3. Bluish limestone, with shell casts and *Exogyra costata*, *Gryphæa mutabilis*, &c, forming top of bluff below warehouse, two hard ledges in it ....20 feet.
4. Sands, traversed by indurated bands of calcareous sand, holding *Exogyra costata* and *Gryphæa mutabilis* chiefly. The sands are white above and dark blue near water level, but the blue sands become white where they crop out up the river near the top of the bluff. Sands contain great numbers of *Ostrea falcata*.....50 to 60 feet.

FIG. 7. *Below Moscow, on the Tombigbee River*

1. Black, shaly clay, devoid of fossils, joints filled with calcite, at mouth of Sucarnochie Creek ....6 to 8 feet
2. Dark blue, shaly, argillaceous limestone and thin, projecting, harder ledges. 30 feet.
3. Ledges of small *Gryphæa* shells ....1 foot.
4. Hard, impure limestones, with *Exogyra costata* and *Gryphæa mutabilis*; irregular, concretionary, sandy ledge above, with comminuted shells, below which a projecting ledge, with many phosphatized shell casts...........................15 feet.



Scale 1 inch = [illegible] feet.

RIPLEY GROUP OF THE CRETACEOUS FORMATION

PLATE XX.

ILLUSTRATING THE PHOSPHATIC GREENSANDS (TOMBIGBEE SAND) AT BASE OF THE ROTTEN LIMESTONE, TOGETHER WITH THE UPPER STRATA OF THE EUTAW FORMATION OF THE CRETACEOUS GROUP.

FIG. 1. *Bluff at Erie, Tuscaloosa River.*

1. Rotten Limestone of the usual character........30 feet.
2. Indurated ledge, calcareous sand, glauconitic and phosphatic, containing oyster shells........7 feet.
3. Yellowish sands, containing shells in upper part........8 feet.
4. Ledge of shells........1 foot.
5. Yellowish, glauconitic sands; more glauconitic below........5 feet.
6. Sandy ledge, with shells........1 foot.
7. Greensand, cross bedded........4 feet.
8. Laminated, blue clay, projecting........2 feet.
9. Phosphatic greensand........1 foot.

FIG. 2. *McAlpine's Ferry, Tuscaloosa River.*

1. Rotten Limestone of variable thickness, with covering of Drift.
2. Calcareous sands, indurated, containing shells, mostly oysters........6 to 8 feet.
3. Sands........8 to 10 feet.
4. Greensand to water level........6 feet or more.

FIG. 3. *Choctaw Bluff, Tuscaloosa River.*

1. Rotten Limestone, with Inocerami and reptilian bones, covering of Drift..20 feet.
2. Indurated calcareous sands, full of shells, glauconitic; upper part = the "Concrete Sand" of Winchell........6 to 7 feet.
3. Yellowish, cross bedded sands, containing oyster shells in upper part, more glauconitic and devoid of fossils below........15 feet.
4. Glauconitic sands and small oyster shells........1 foot.
5. Phosphatic greensand........6 to 8 feet.

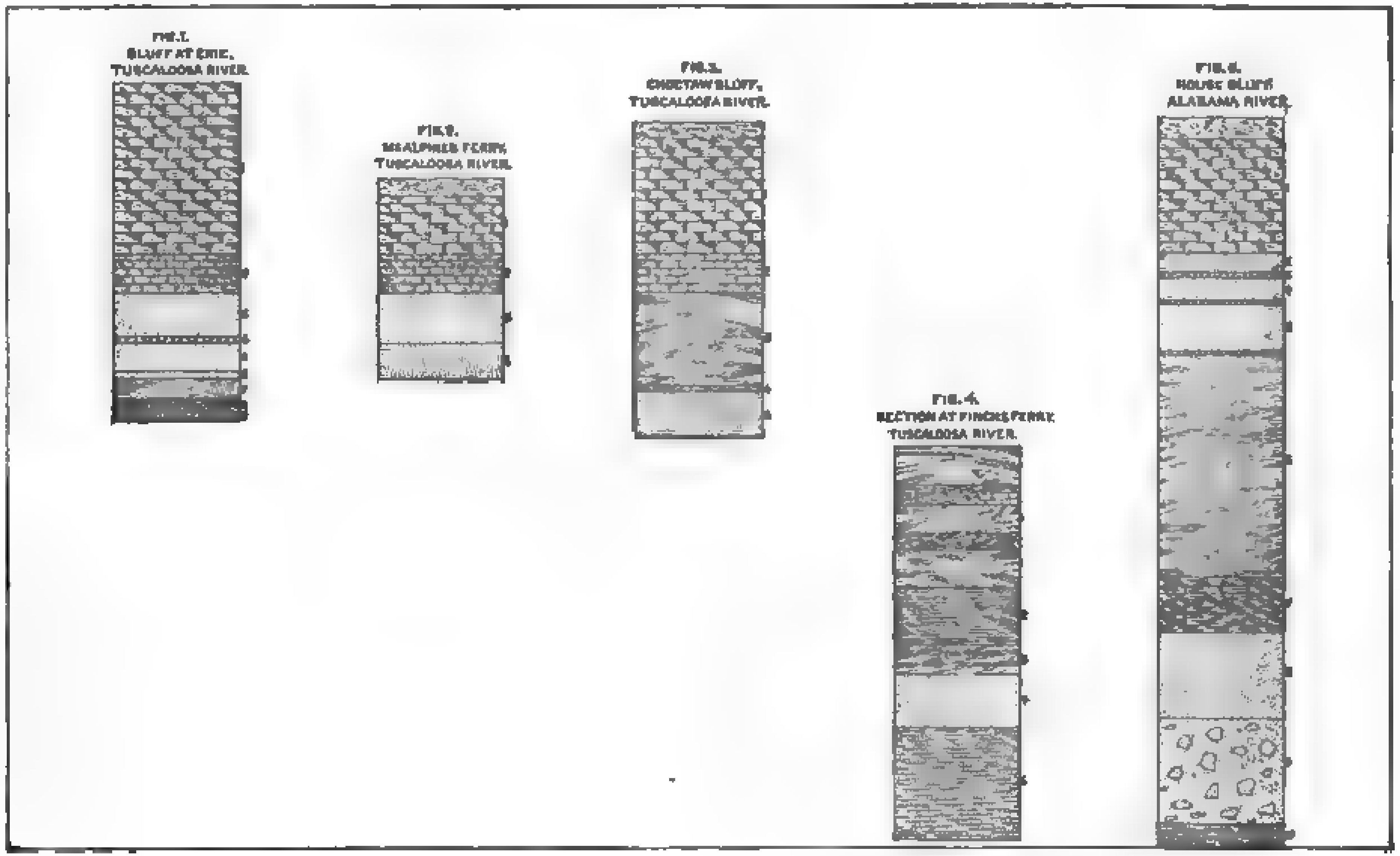
FIG. 4. *Section at Finch's Ferry, Tuscaloosa River.*

1. Yellowish, cross bedded sands, with indurated bands at intervals; contains a few casts of shells, mostly oysters, and pieces of silicified wood........25 feet.
2. Laminated, blue clays, with sand between the laminæ........10 feet.
3. Alternations of cross bedded sand and blue, laminated clay........5 feet.
4. Bluish, glauconitic sands........10 feet.
5. Laminated, blue clays, the laminæ separated by sand........20 feet.

FIG. 5. *House Bluff, Alabama River.*

1. Rotten Limestone........20 feet.
2. Greensand, with phosphatic nodules........4 feet.
3. Bed of shells in sand........1 foot.

4. Light colored sands, with irregular deposits of shells and shell bed at base. 5 feet.
5. Sands, with layer of shells at base .... 9 feet.
6. Alternating beds of horizontally laminated and cross bedded sands, yellow (glauconitic), the separate beds from 1 to 2 feet thick, marked with streaks deeply colored by iron .... 40 feet.
7. Laminated clays (soapstone), devoid of fossils .... 10 feet.
8. Blue, micaceous sands, no fossils observed .... 15 feet.
9. Light colored sands, with large, bowlder-like concretion .... 20 feet.
10. Alternations of laminated clays and blue sands to water level.



Scale 1 inch = 10 feet

PHOSPHATIC GREENSANDS AT THE BASE OF THE ROTTEN LIMESTONE

PLATE XXI.

GENERAL SECTION OF TERTIARY AND CRETACEOUS STRATA OF ALABAMA, AS EXPOSED ALONG THE ALABAMA, TOMBIGBEE, AND TUSCALOOSA RIVERS.

COLUMN 1. *Exposures inland near Alabama River.* (*Supplementary to Alabama River section.*)

Hills back of Yellow Bluff.

1. Gray, sandy clays, alternating with cross bedded sands, seen in hill back of Yellow Bluff; barometric measurement .... 90 feet.
2. Gray, sandy clays, alternating with cross bedded sands, like the preceding; seen in hill at top of Yellow Bluff .... 40 feet.
3? Greensand marl, Wood's Bluff .... 6 to 15 feet.
4. Gray, sandy clays of purple tinge, including four or five thin seams of lignite. Top of Yellow Bluff .... 40 feet.

Grampian Hills.

5. Gray, sandy clays, indurated, in part glauconitic, and filled with shell casts, chiefly of Turritella, in part closely resembling Buhrstone clays .... 47 to 50 feet.
6. Glauconitic sands, with *Gryphæa thirsæ*, several indurated bands .... 25 feet.

On Pursley Creek.

7. Glauconitic sands, with *Gryphæa thirsæ*, clayey above .... 12 feet.
8. Laminated sand and sandy clays .... 15 feet.
9. Yellowish gray, cross bedded sands, indurating, with bowlders, inclosing lenticular sheets of clay .... 25 feet.
10. Gray sands and clays, interstratified, glauconitic; lignite at base; seen in Pursley Creek .... 20 feet.

Oak Hill, Graveyard Hill, and Pine Barren Creek.

11. Gray, sandy clays, cross bedded sands, and thin, laminated clays in many alternations .... 108 feet.
12. Gray clay, breaking into cuboidal blocks, 15 feet, passing into black clay marl, Matthews's Landing .... 23 feet.
13. Yellowish, calcareous sands and sandy shales, with hard ledges and 3 feet hard, yellowish, phosphatic, sandy limestone at base .... 31 feet.
14. Yellow, calcareous clays, passing below into black, all holding Black Bluff fossils .... 35 feet.
15. Argillaceous white limestone; Nautilus Rock 10 feet, with 6 feet calcareous sands below .... 16 feet.
16. Crystalline limestone and Turritella Rock .... 8 to 9 feet.
17. Yellowish, micaceous sand, with Ripley fossils .... 55 feet.
18. Bluish gray, calcareous sands, hard, projecting layers .... 15 feet.

Near Vinton, Autauga County.

19. Thinly laminated, white and pink and purple clays, with small percentage of pink, purple, and yellow sand .... 30 feet.
20. Purple and mottled clays 12 feet, red sands 5 feet, and white and yellow, laminated clays 8 feet .... 25 feet.
21. Variegated pink and micaceous sands .... 6 feet.
22. Mottled, yellow and purple, sandy clays and sands, on the banks of Mulberry Creek .... 20 feet.

Soap Hill, Bibb County.

23. Clayey sands in several ledges .... 10 feet.
24. Cross bedded, yellowish white sands, indurating into sandstones at intervals .... 30 feet.

25. Laminated, gray clay, with partings of sand 10 feet, overlying 40 feet of laminated clays and cross bedded sands ....50 feet.
26. Laminated, gray, sandy clays, with leaf impressions, sand at base ....20 feet.

Near Tuscaloosa.

27. Variegated, purple sands, sheet of ferruginous sandstone on top ....8 feet.
28. Purple clay, with partings of sand ....10 feet.
29. Gray, yellow sands and clays, ferruginous ledge on top.............................8 feet.
30. Thin bed of lignite in clays, over gray mass. Not seen ....about 20 feet.
31. Purple clays, with two ledges of sandy iron ore......................40 to 50 feet.

COLUMN 2. *Section exposed on Alabama River.*

Marshall's Landing to Lisbon.

1. *Vicksburg.* White Limestone, with *Orbitoides Mantelli*, hill back of Claiborne, also back from river, from Marshall's Landing to Gainestown..at least 140 feet.
2. *Jackson.* Argillaceous White Limestone, with bones of *Zeuglodon Cetoides*, phosphatic nodules, and marls, from Claiborne to Marshall's Landing ......60 feet.
3. Scutella bed, followed by coarse, ferruginous sands, of which 17 feet is highly fossiliferous; hard, sandy ledge at base ....30 feet.
4. Calcareous clay, alternating with greensand containing *Ostrea sellæformis*.25 feet.
5. Light gray, calcareous sands, traversed by hard, sandy ledges, clayey in part, *Ostrea sellæformis*, characteristic greensand, and shells at base...................35 feet.
6. Blue clay, passing into greensand, upper half with few fossils, lower half highly fossiliferous............ ....22 feet.
7. Calcareous, clayey sands............... ....9 feet.
8. Coarse ferruginous marl 3 feet, followed by 20 feet of light yellow sands, few fossils...23 feet.
9. Bluish, jointed clay ....12 feet.

Hamilton's Landing.

10. Light colored, aluminous sandstones, claystones, and silicious sandstones .75 feet.

Yellow Bluff, Bell's Landing, and Lower Peach Tree.

11. Reddish, cross bedded sands, 2 feet lignite at base ....22 feet.
12. Laminated, sandy clays, gray color ... .15 feet.
13. Yellow sands, passing below into gray, laminated, sandy clays ....25 feet.
14. Greensand marl, Bell's Landing .. ..10 feet.
15. Gray, laminated, sandy clays 22 to 25 feet, passing into clay marl, Gregg's Landing, 5 feet ....30 feet.
16. Sandy clays of prevailing gray color, varying in degree of sandiness and coarseness of lamination, 1 foot greensand marl at base............... ....50 feet.
17. Gray, sandy clays .. ..10 feet.

Gullette's Landing

18. Gray, sandy clays, alternately thin, laminated, and heavy bedded; indurated by glauconitic clay on top and greensand bed in middle ....37 feet.
19. Glauconitic sands, with *Gryphæa thirsæ*, indurated ledges passing through beds........ ....18 feet.
20. White, cross bedded sands . ...12 feet.
21. Bluish, clayey, glauconitic sands, with *Gryphæa thirsæ*, several hard ledges 50 feet.

Parsley Creek to Coal Bluff

22. Glauconitic, clayey sands of varying degree of hardness, bed of lignite 4 feet (Coal Bluff) at base ....35 feet.
23. Gray, sandy clays . ...10 feet.

Burford's Landing.

24. Gray clay, cross bedded sands, Burford's Landing ....10 feet.

Walnut Bluff to Clifton.

25. Gray, sandy clays, forming river banks from Walnut Bluff to Clifton...35 (?) feet.

Matthews's Landing.

26. Black, sandy clay marl, micaceous, Matthews's Landing................20 feet.

Midway to Prairie Bluff.

27. Black clay, Midway ....5 feet.
28. Argillaceous White Limestone (Nautilus Rock) ....10 feet.
29. Crystalline limestone (*Turritella*) back of Bridgeport.
30. Yellowish, micaceous sand (Ripley fossils) at Bridgeport and hills back of landing..55 feet.
31. Dark bluish gray, sandy, micaceous clays, weathering into yellowish shales, with indurated, sandy, projecting ledges at intervals of 5 to 10 feet throughout whole thickness, exposed at Bridgport, Tear Up Creek, Canton Landing, and hills back of Prairie Bluff, and in Gee's Bend...100 feet.
32. Bluish, argillaceous limestone, with phosphatized shell casts &c., Ripley formation ....30 to 35 feet.
33. Sands of various colors, dark blue, gray to white, traversed by indurated bands of calcareous sands with Cretaceous shells.................................60 feet.

Rotten Limestone, Bridgeport to House Bluff.

34. Highly argillaceous limestone, with ledges holding many shells (*Ostrea, Gryphæa, Exogyra*) ....1,000 feet.

House Bluff.

35. Hard, calcareous sands, with fossils strongly phosphatic in part..........20 feet.
36. Alternating layers of horizontally laminated and cross bedded, yellowish (glauconitic) sands...40 feet.
37. Laminated, blue clays...10 feet.
38. Blue, micaceous sands ....15 feet.
39. Light colored, micaceous sands ....20 feet.
40. Laminated clays and blue sands, thickness not determined.

COLUMN 3. *Section exposed on the Tombigbee (including the Tuscaloosa) River.*

St. Stephens and Baker's Bluff.

1. *Vicksburg.* White Limestone, with *Orbitoides Mantelli*, forms upper 70 feet of Saint Stephens Bluff, upper part of Baker's Hill, and greater part of river bluffs, down to Oven Bluff...140 feet.
2. *Jackson.* Argillaceous White Limestone lower part of Saint Stephens and Baker's Bluffs ....60 feet.
3. Scutella bed, underlaid by coarse greensand and Claiborne fossiliferous sands ....15 feet.

Coffeeville Landing.

4. Yellowish gray, calcareous sands, with *Ostrea sellæformis*, clayey in part, traversed by hard, sandy ledges, greensand, with comminuted shells at base .....35 feet.
5. Bluish clay ....7 feet.

Hatchetigbee to mouth of Bashi Creek.

6. Aluminous sandstones, claystones, &c., of jointed structure, forming at White Bluff a perpendicular cliff...115 feet.
7. Brown clays, sandy, non-fossiliferous, 30 feet, followed by 3 feet marl and 15 feet purplish brown, sandy clays; then 28 feet of sands, striped with brown clays and inclosing two beds with marine shells; in all.....................75 to 76 feet.
8. Dark gray, sandy clays, striped with brown or purple, sandy clays. Very few fossils exposed at Davis's Bluff, White's Bluff, and McCarthy's Bluff...100 feet.

9. Clayey marl, passing into a greensand marl 18 feet thick ....31 feet.
10. Gray, clayey sands, with four or more thin seams of lignite................25 feet.

Tuscahoma to Shuquabowa Creek.

11. Laminated sands and indurated sands, with bowlders........................30 feet.
12. Gray, sandy clays, striped with somewhat harder, projecting ledges..35 to 40 feet.
13. Greensand marl (Bell's Landing) ....7 feet.
14. Sandy, laminated clays ....15 feet.

Horse Creek to Gay's Landing.

15. Gray, sandy clays, rather thin bedded; hard, sandy ledge at base..........28 feet.
16. Glauconitic sands and clays, with *Gryphæa thirsæ*.........................18 feet.

Lott's Ferry to Nanafalia.

17. Glauconitic sands, with *Gryphæa thirsæ*, at Lott's Ferry, Eureka Landing, and Nanafalia Landing..35 feet.
18. Black clay, passing into greensand marl, with *Gryphæa thirsæ* ....18 feet.

Landrum's Creek.

19. Black, micaceous, glauconitic sands..15 feet.
20. Lignite 7 feet and 5 feet gray clay below..................................12 feet.

Tompkinsville to Naheola.

21. Gray, sandy clays, cross bedded sands and laminated clays in many alternations ....80 feet.
22. Greensand marl (Naheola), with black clay below ....20 feet.

Naheola to Black Bluff.

23. Between Naheola and Black Bluff, black clays.................thickness unknown.
24. Yellowish clays 30 feet, underlaid by 50 feet of black in dark brown, slaty, fossiliferous clays, Black Bluff fossils...80 feet.

Moscow.

25. Dark blue or black, sandy clays, with indurated bands, calcareous below, passing into an argillaceous limestone 16 to 18 feet, with phosphatized shell casts ....55 feet.

Rotten Limestone, Moscow to Choctaw Bluff.

26. Argillaceous limestone, with hard ledges, holding many shells (*Ostrea*, *Exogyra*, *Gryphæa*) ....1,000 feet.

Choctaw Bluff to Big Log Shoals.

27. Hard, calcareous sands, highly fossiliferous, 6 to 8 feet; thin, yellow, cross bedded sands, 15 feet; and below this a phosphatic greensand, 8 to 10 feet..about 25 feet.
28. Cross bedded, glauconitic sands, with thin clay partings, yellowish color prevailing ....40 feet.
29. Dark gray, laminated, sandy clays, alternating with bluish sands ..15 to 20 feet.
30. Laminated sands and clays, alternating with cross bedded sands ..... 40 (?) feet.
31. Compact, micaceous sands, cross-bedded sands, laminated clays, in many alternations, including two small beds of pebbles and thin bed of lignitic matter ....60 (?) feet.

White's Bluff.

32. Purple and mottled clays, 10 feet, with 15 feet of yellow, micaceous sands below ....25 feet.

Steele's Bluff.

33. Purple and mottled clays, 10 feet, with 10 feet light yellow, coarse, cross bedded pebbly (chert) sands ....20 feet.

Williford's.

34. Purple and mottled clays ....10 feet.

Mrs. Prince's.

35. Purple and mottled clays..........10 feet.

Saunders's Ferry to Tuscaloosa.

36. Dark gray, laminated clays, sandy partings, 25 feet, and gray sands, indurated, 15 feet, at Venable's and near Saunders's Ferry..........40 feet.
37. Sandy clays, with leaf impressions, black scales like graphite, fragments of lignitized stems.

COLUMN 4. *Exposures inland near Tombigbee and Tuscaloosa Rivers. (Supplementary to the Tombigbee River section.)*

Salt Mountain.

1. White Limestone, in part crystalline, filled with masses of coral..........150 feet.
2. Orbitoidal White Limestone..........20 feet.

Hills west of McCarthy's Ferry.

3. Aluminous sands, indurated clays or claystones, silicious sandstones, &c., forming hills west of McCarthy's Ferry, in Choctaw County, 270 feet in one exposure, with 15 feet laminated clays at base; in all..........285 feet.

Bladen Springs boring.

4. Loose surface materials, varying slightly in color and texture..........80 feet.
5. Alternations of blue and sandy marl (clay), with indurated blue ledge 5 feet thick at base..........81 feet.
6. Soft, clayey marl..........23 feet.
7. Greensand, with shells, 3 feet, followed by 22 feet alternating hard and soft beds, the latter fossiliferous, water bearing..........25 feet.
8. Marls or blue clays..........46 feet.
9. Brown and blue marls (clays) in many alternations (lignitic ?)..........21 feet.
10. Blue marls or clays, with 2 feet of greensand at base..........61 feet.
11. Lignite, 5 feet, followed by 19 feet of brown, tough marl (clay)..........24 feet.
12. Blue, sandy marl, with many varieties of shells; *Venericardia planicosta* recognized..........23 feet.
13. Blue, sandy marl (clay)..........58 feet.
14. Brown marl (clay) 5 feet, with 32 feet blue marl below..........37 feet.
15. Greensand marl, 9 feet, followed by 37 feet of blue marl (clay). At 500 feet water was struck, which flowed 10 feet above surface..........46 feet.
16. Brown clay marl, 19 feet, followed by 15 feet blue clay, with greensand, containing shells..........34 feet.
17. Brown marl, resembling soapstone; contains shells; stream of water near bottom which flowed 30 feet above surface..........50 feet.
18. Gray, sandy marl, with shells..........15 feet.
19. Gray, sandy marl, with shells; more clayey than preceding..........64 feet.
20. Very tough, blue marl (clay), at base of which a thin layer of white sand and then a thin layer of greensand..........71 feet.
21. Brown marl (clay) 5 feet, followed by alternating beds of clay and sand, mostly sand (*first salt water*)..........20 feet.
22. Alternations of gray and brown sand, with marl (clay)..........26 feet.
23. Tough, blue marl, clay (*big vein of salt water*)..........13 feet.
24. Sand and clay alternating..........14 feet.
25. A kind of white limestone (?) containing mica, passing below into 3 feet blue, sandy marl, containing shells..........28 feet.
26. Blue marl (clay) 14 feet, followed by 14 feet of blue marl and sand, numerous shells..........28 feet.
27. Marl, 12 feet, with streaks of sand, followed by brown sand and blue marl, 12 feet..........24 feet.

CARBONIFEROUS STRATA OF ALABAMA.

... 11 feet.

... of white, blue, and gray ...

... 29 feet.

... with several ledges of ...

... 1 foot thick at 971 feet.

... at 1,000 feet ... 137 feet.

... of dark blue clay, some of it ...

... 39 feet.

... 13 feet.

... sandy clay ... 17 feet.

... moderately hard, gray ...

... to bottom of boring ...

... probably 125 feet.

... shells and containing ...

... 150 feet.

... 40 feet.

... bluish white limestone,

... 75 feet.

... 55 feet.

... 47 feet.

... 38 feet.

... 105 feet.

... 32 feet.

... 78 feet.

... 11 feet.

... changes in color and ...

... 250 feet.

... sandstone 17 feet.

... sandstone 2 feet.

... 25 feet.

... 10 feet.

... purple,

... 40 feet.

0. ...

d. Ligh...

with ...

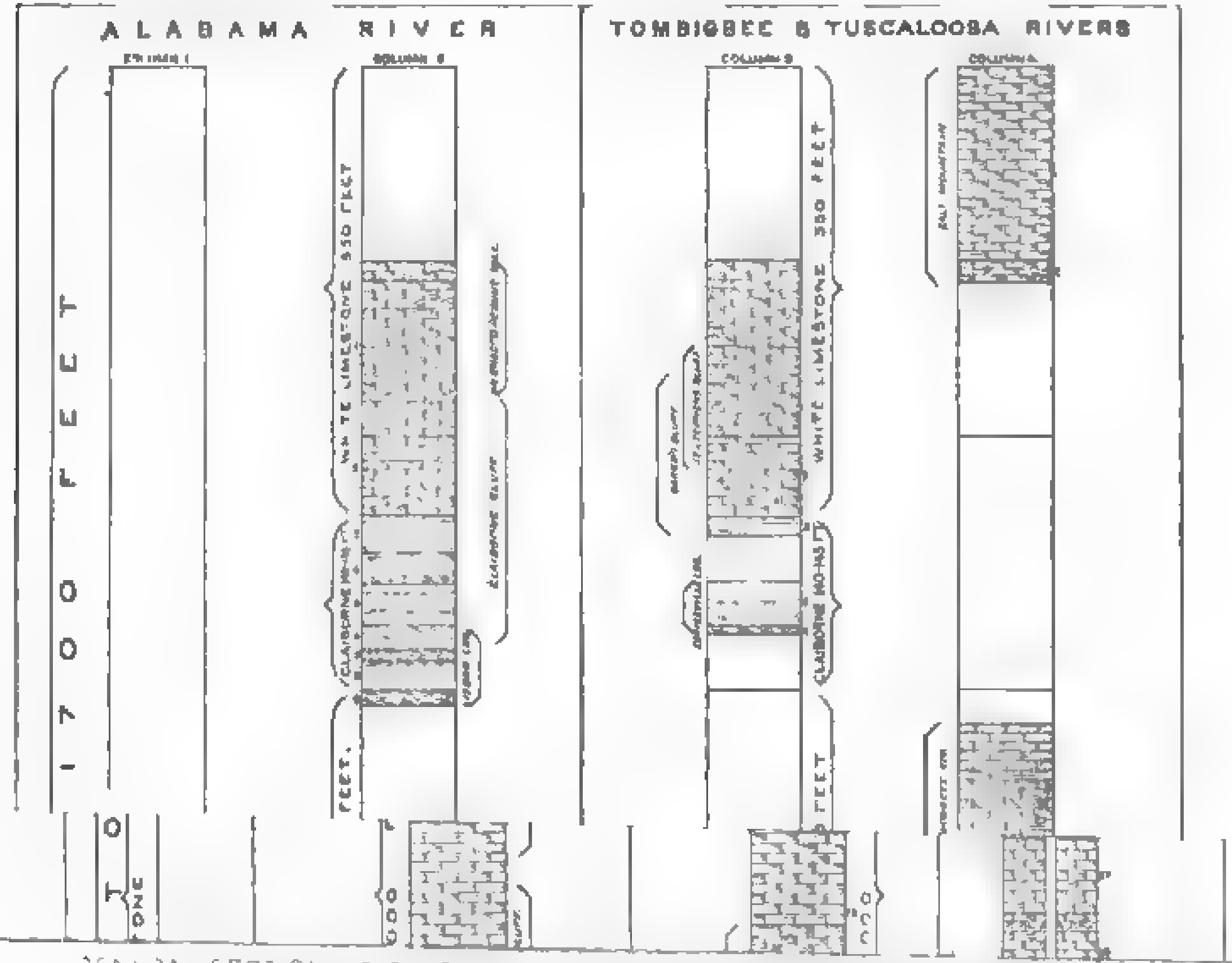
... Sandy

... feet.

... 22 feet.

... feet.

... 20 feet.



GENERAL SECTION OF TERTIARY AND CRETACEOUS STRATA OF ALABAMA AS EXPOSED
ALONG THE ALABAMA, TOMBIGBEE, AND TUSCALOOSA RIVERS

28. Greenish rock, chalky above, hard below ....11 feet.
29. Sandstone 4 feet, followed by 25 feet quicksand, of white, blue, and gray colors (*strong stream of salt water*) ....29 feet.
30. Marls or clays, mostly of grayish or light brown colors, with several ledges of extremely hard rock, e. g., one 2 feet thick at 966 feet, one 1 foot thick at 971 feet, one 3 inches thick at 978 feet, one 1 foot thick at 1,009 feet ....137 feet.
31. Tough black clay, 2 feet, followed by 99 feet of dark blue clay, some of it quite hard and firm; some very soft and sticky ....99 feet.
32. Snuff colored clay, soft and sticky ....13 feet.
33. Gray sand and shells 12 feet, followed by 5 feet soft, sandy clay ....17 feet.
34. Hard ledge 4 inches at top, below which 125 feet of moderately hard, grayish or blue rock, with scarcely any change in color or texture, to bottom of boring; no shells observed; Rotten Limestone ....probably 125 feet.

Livingston artesian well boring.

35. Soft, blue, argillaceous Rotten Limestone, thickly set with shells and containing iron pyrites ....180 feet.
36. Hard, white limestone, with few shells ....50 feet.
37. Hard, blue limestone 7 feet, followed by 68 feet of pure, bluish white limestone, with few if any shells ....75 feet.
38. Very hard, white limestone, stratum of oyster shells near top ....55 feet.
39. Light blue limestone, not so hard as preceding ....47 feet.
40. Bluish brown limestone, filled with small shells, rather sandy ....58 feet.
41. Hard, white limestone ....105 feet.
42. Soft, blue limestone, 2 feet brown rock at top ....22 feet.
43. Rather soft, brownish blue limestone ....78 feet.
44. Very soft, blue limestone, hard ledge at top ....11 feet.
45. White limestone, moderately soft, with occasional slight changes in color and hardness ....250 feet.
46. Hard sandstone 6 feet, 10 feet sand, water bearing, and 1 foot sandstone ..17 feet.
47. Coarse greensand 38 feet, sandstone 2 feet, greensand 25 feet, sandstone 2 feet, and greensand again 18 feet, water bearing at 1,005 feet ....85 feet.
48. Fine greensand, flint layer on top ....10 feet.

Strata of Tuscaloosa formation

Near Havana

49. Yellow sand and pebbles 10 feet, overlying 30 feet of variegated, pink and purple, micaceous, cross bedded sands, near Havana ....40 feet.

Big Sandy Creek

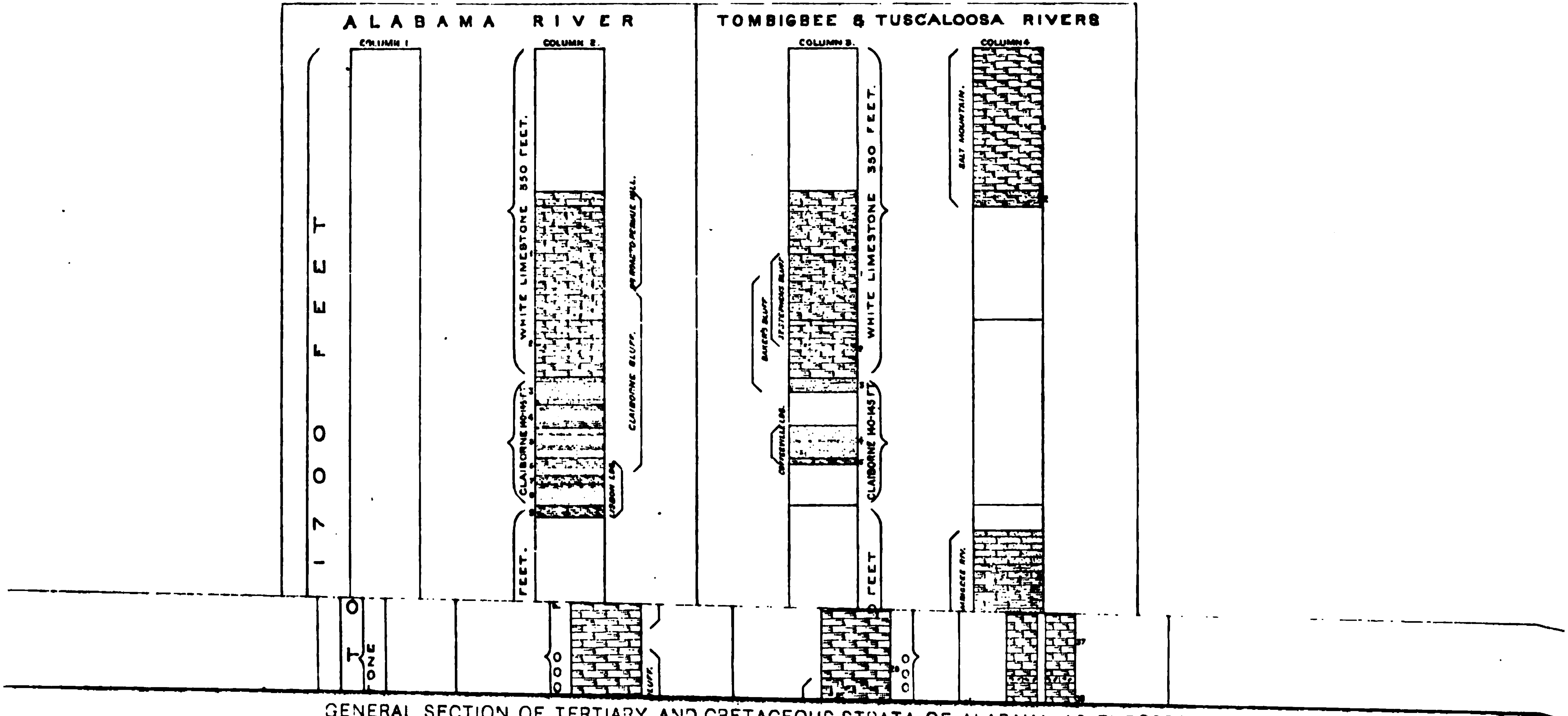
50. Purple and mottled clays seen along road leading up hill from Big Sandy Creek ....50 feet.
51. Light yellow sands and pebbles 15 feet, with 8 feet dark gray, laminated clay, with lignitized trunk, Big Sandy Creek ....23 feet.

Little Sandy Creek.

52. Yellow, micaceous sands, overlying dark gray, micaceous, laminated clays. 8 feet.
53. (Belongs to a recent formation)

Tuscaloosa City.

54. Dark gray, laminated clays, with leaf impressions. ....8 feet.
55. Light colored, sharp, cross bedded sands ....20 feet.



GENERAL SECTION OF TERTIARY AND CRETACEOUS STRATA OF ALABAMA, AS EXPOSED ALONG THE ALABAMA, TOMBIGBEE, AND TUSCALOOSA RIVERS.

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NOTICE.

The bulletins of the United States Geological Survey are numbered in a co[illegible] [illegible] series, and will be bound in volumes of convenient size.

This bulletin will be included in Volume VII.